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Journal of the

SANITARY ENGINEERING DIVISION

Proceedings of the American Society of Civil Engineers

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NEW DEVELOPMENTS IN SEWAGE SLUDGE TREATMENT

Frederick G. Nelson,[1] F. ASCE and William E. Budd,[2] M. ASCE

Reduction in digestion volume requirements utilizing decreased detentions, pre-thickening and gaseous mixing has been a primary goal of recent developments. Advances in sludge filtration have resulted from a wider variety of media and tolerance of higher filtrate suspended solids. Other dewatering developments are revived interest in centrifugation and a new wet oxidation process.

INTRODUCTION

The method of sewage sludge treatment consisting of separate sludge digestion and dewatering on sludge beds or vacuum filters has become an accepted method of treatment in virtually every sewage treatment plant of any size. However, since the advent of separate sludge digestion in 1923, and the application of heat to a sludge digester in 1927, very little advancement has been made in this field and the same practice and design requirements are still being followed thirty-one years later. It has only been during the past 5 - 6 years that some developments have been demonstrated that result in appreciable economy and improvement in performance.

The new developments in this field have been directed toward the reduction of volume required for satisfactory sludge digestion, with as satisfactory end results as previously attained, and increased production rates and economy in the field of sludge dewatering. It is the purpose of this paper to review some of these developments.

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Accelerated Digestion

The last 5 - 6 years have seen several articles appearing in the technical literature reporting on pilot and full-scale digester operation at greatly reduced volumes. From these reports, it was evident that the field was progressing into the era of the so-called high rate digester. Torpey[1,2] demonstrated on a plant scale that volatile solids loadings five times that of conventional standards and detention times as low as eleven days were practical with the end results equal to those formerly obtained when using 54 days of digester detention. In pilot plant studies, Torpey,[3] has shown also satisfactory digester operation at volatile solids loadings about twelve times conventional with detention periods slightly under four days. Morgan,[3] has reported on pilot studies with volatile solids loadings five to seven times conventional, and detention periods in the range of seven to eight days. Blodgett,[4] has reported on the operation of a plant digester at volatile solids loadings at approximately three times conventional, and detention periods as low as fourteen days. Sawyer and Roy,[5] have also shown on a laboratory scale that digestion is feasible at loadings of five to seven times conventional at detention periods as low as six days.

In reviewing the above reports on these investigations as tabulated in Table 1, it is noted that full scale digesters have been operated at average loadings up to 0.18 lbs of volatile solids/cu ft per day, and at detentions as low as fourteen days. Laboratory and/or pilot studies indicate that digestion has been attained at loadings up to 0.42 lbs of volatile solids/cu ft/day at detention periods as low as five days.

After reviewing the reports of these investigations, it is concluded that the successful operation of a high rate digester unit appears to hinge on the following critical requirements:

1. Continuous mixing of the entire digester contents to control separation of solids into a scum layer and to distribute the incoming feed to the digester contents.
2. Feeding as concentrated a sludge as possible.
3. Feeding on a substantially continuous basis.
4. Feeding sludge that has been degritted to the point that no grit will settle out in the digester compartment and take up valuable digester space, i.e., full utilization of the digester volume.

TABLE I

AUTHOR	YEAR	PERIOD OF DATA	DIGESTER VOLUME, CU.FT.	TYPE OF SLUDGE	FEED SLUDGE % T.SOLIDS	FEED SLUDGE % VOLATILE	VOLATILE LOADING LBS/CU.FT./DAY	DETENTION IN DAYS	% VOL.SOLIDS REDUCTION	GAS - CU.FT. PER LB.OF VOLATILE ADDED	GAS - CU.FT. PER LB.OF VOLATILE DESTROYED
TORPEY	1953	5.5 MO.	180,000	PRIMARY & MODIFIED ACTIVATED	6.0	71.9	.18	15.0	48	9.2	19.4
	1953	PERIOD #5 25 DAYS	6	PRIM. & ACT. SLUDGE	4.2	73.6	.42	4.7	38	8.6	22.2
MORGAN	1953	10 MO.	150	PRIMARY & TRICKLING FILTER	6.12	62.7	.277	8.7	47	8.85	18.8
BLODGETT	1953	4 MO.	106,000	PRIMARY & ACTIVATED	6.6	59.75	.171	14.40	37	7.1	19.1
SAWYER & ROY	1955	2.5 MO.	6 LITERS	PRIMARY	4.42	74.5	.35	6	52.2	8.9	17.0

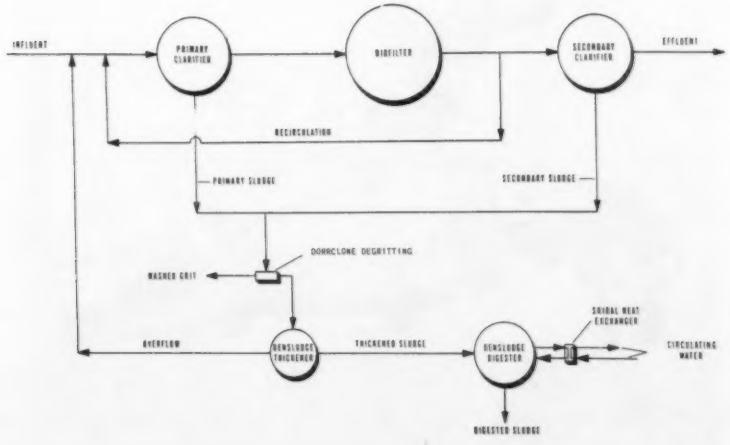
All of the above requirements are absolutely essential if a high-rate digester is to have stability of operation and produce a well-digested sludge.

To date, two commercial companies have spent time and effort in developing digestion systems operating in the loading ranges attained by the above investigators. These systems are the Densludge Digestion System and the Catalytic Reduction Process. These two systems differ basically in that the Densludge System removes the available water before digestion and, therefore, has no digester supernatant, while the Catalytic Reduction Process removes the water after digestion resulting in digester supernatant being returned to the main treatment process.

Densludge Digestion System

The Densludge Digestion System (Fig. 1), utilizes a degritting DorrClone unit, a sludge Thickener, sludge digester with high capacity mixing, and a sludge storage tank if required. Each of these units is a vital part of the system if stable operation is to be obtained at these lower design detentions.

Dilute sludge underflow is continually pumped from the primary and secondary Clarifiers and discharged to a DorrClone degritter where a 150 - 200 Mesh grit separation is attained. Grit free overflow from the DorrClone Classifier flows to the sludge Thickener for solids concentration. The overflow from the Thickener, equivalent to the quality of raw sewage in BOD and suspended solids, is returned to the raw sewage flow. The concentrated sludge in the Thickener underflow is pumped to the digester equipped with high capacity Draft Tube Mixers where digestion occurs at elevated loadings (lbs volatile solids/cu ft/day). Since all readily available water has been removed before digestion, a further separation of liquid is unnecessary resulting in no supernatant being returned. Therefore, digested sludge is discharged to storage or to ultimate disposal as dictated by local conditions.



BIOFILTER FLOWSHEET WITH DENSLUDGE DIGESTION SYSTEM

Fig. 1.

A recent development in the degritting of sewage sludge is the DorrClone degritter as shown in Fig. 2. This unit operates on the centrifugal theory whereby the heavier solids are thrown to the outside wall of the DorrClone unit, forced down the inside wall of the cone, and discharged through the underflow valve. The overflow is discharged through a vortex finder and continues to a sludge Thickener.

Table 2 indicates data collected on a test unit installed at the San Mateo, California Sewage Treatment Plant where it operated on a primary Clarifier underflow. These data indicate that of the grit removed in the underflow of the DorrClone unit, 95% was +200 mesh. The putrescible solids content of the separated grit was 1.45%, thus indicating a very clean product. The removal of the 150 to 200 mesh material is considerably above the 65 mesh separation practiced in the Sanitary field to date. However, with the increased loadings and lower detentions now being recommended for the design of sewage sludge digesters, it becomes more and more important that this fine grit be kept from the sewage sludge digester, and the entire volume be used for sludge digestion and not grit storage.

Torpey,(6) has shown that it is practical to successfully thicken sewage sludges in a separate sludge Thickener. Brisbin,(7) by pilot test at Middleboro, Massachusetts high-rate trickling filter plant, demonstrated it was practical to thicken dilute sludges in a separate tank to a concentration previously unattainable. Daily pumping, which previously had been 520 cu ft per million gallons of sewage, was reduced to 162 cu ft per million gallons of sewage or approximately 70%. Digestion studies also carried on at Middleboro (Table 3), indicated these concentrated sludges behaved in a digester similar to a more dilute sludge, but had a greater buffering capacity as shown

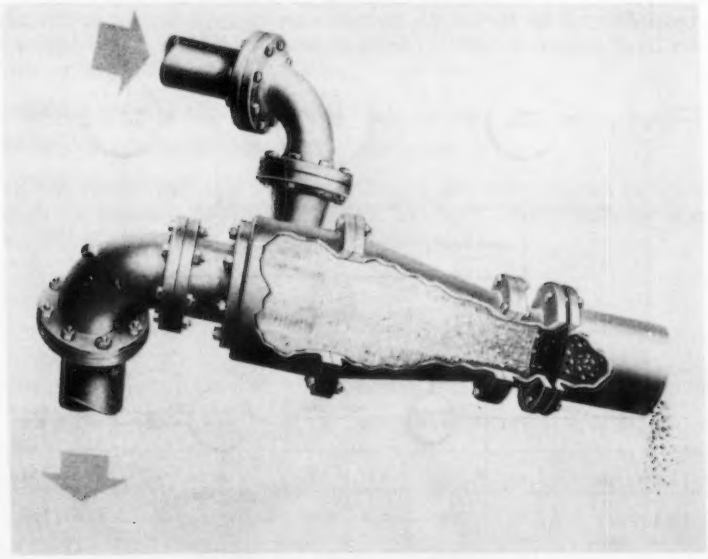


Fig. 2. The FR DorrClone for Sewage Degritting.

by the higher alkalinity levels. It was found at Middleboro, and has been reported by Sawyer and Roy,(5) that the alkalinity in the digesting sludge increased in direct proportion to the solids content of the sludge being fed to the digester. It was also noted that fluctuations of daily loads more easily affected the digester adversely in the early operation when alkalinities were in the range of 1700 to 2000 ppm, than they did in later operation when the alkalinity concentration was in the order of 5000 to 6000 ppm.

During the progress of this pilot digester work, it was also evident that mixing was a very critical point in the successful operation of a high-rate digester. It was observed that an interval of one day without mixing could adversely affect the operation of the high rate digester as noted by rising volatile acids concentration and excessive scum formation.

During the Summer of 1956, pilot plant tests were instituted at the Grass Island Primary Sewage Treatment Plant at Greenwich, Connecticut. The pilot plant consisted of a 7' diameter thickening tank and 8' diameter digestion tank

TABLE 2

GRIT SAMPLE FROM DORRCLONE TESTS AT SAN MATEO, CALIFORNIA

PER CENT PUTRESCRIBLE MATERIAL - 1.45

SIEVE ANALYSIS

MESH	DORRCLONE UNDERFLOW - % CUMULATIVE
6	1.625
8	5.5
10	11.6
14	22.1
20	35.4
28	48.9
35	65.3
48	79.9
65	90.0
100	92.9
150	94.4
200	95.2

TABLE 3

MIDDLEBORO, MASS. - PILOT TESTS

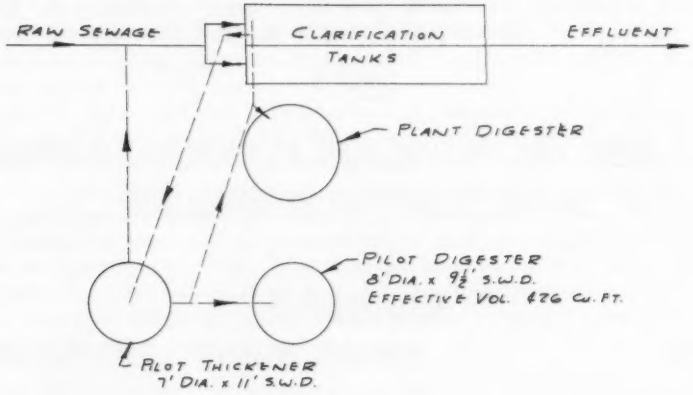
PERIOD	DIGESTER DISPLACEMENT DAYS	RAW SLUDGE		LOADING LBS. VOL. SOLIDS/ CU.FT/DAY	DIGESTER LIQUOR						GAS-CU.FT./LB. VOL.MATTER		CU.FT.GAS/ CU.FT. DIGESTER/ DAY	% VOL. SOLIDS REDUCTION
		% T.SOLIDS	% VOL. SOLIDS		pH	TEMP. °F	ALKALINITY	VOL. ACIDS	% TOT. SOLIDS	% VOL. SOLIDS	ADDED/DAY	DESTROYED/DAY		
1	36	8.1	82	0.13	-	91.5	4500	880	4.4	63	-	-	-	62
2	22	8.3	71	0.17	7.2	91.5	3260	275	2.1	58	7.3	16.5	1.2	44
3	19	7.2	79	0.19	7.4	94	5740	430	4.3	62	8.2	14.4	1.4	57
4	17	10.1	76	0.27	7.2	92	3870	335	3.8	60	6.3	12.0	1.8	52.7
5	16	7.2	80	0.22	7.3	93	5680	1200	4.2	65	8.2	15.2	1.7	54
AVG.	22	8.2	78	0.20			4610	624	3.8	62	7.5	14.5	1.5	53.9

DIGESTER CAPACITY - 426 CU.FT. - CONTINUOUS MIXING.

as shown in Figure 3. The results of these thickening and digestion studies, as shown in Table 4, again indicated it was practical to thicken sludges from primary settling tanks to a point where no further liquid separation was required, and to digest these sludges at loading five to seven times conventional.

Average Thickener loadings were approximately 20 lbs of dry solids per sq ft per day resulting in a Thickner underflow of approximately 9.1% solid and an overflow similar in percent solids to that of the raw sewage.

The decrease in raw sludge pumpage is particularly revealing. During the year of 1955, the pumpage figures from the primary Clarifiers at Greenwich to the plant Digester averaged 500 cu ft/MG of raw sewage. Between



GREENWICH, CONN. - PILOT TESTS

FIG. 3

TABLE 4

GREENWICH, CONN. - PILOT TESTS

THICKENER

PERIOD 1956	THICKENER INFLUENT: TEMP. °F	OVERFLOW RATE GAL/SQ.FT/DAY	SOLIDS LOADING LBS/SQ.FT/DAY	THICKENER UNDERFLOW: % TOT. SOLIDS	% VOL. SOLIDS	CU.FT/DAY	CU.FT/DAY/M.G.SEWAGE	THICKENER OVERFLOW SUS. SOLIDS (ppm)
JULY[3]	63	680	23.0	10.0	73.4	112	107	-
AUG.	66	680	17.9	8.3	79.0	117	125	240
SEPT.	68	680	18.5	9.0	78.0	113	113	200
AVG.	-	-	-	9.1	76.8	114	115	220

DIGESTER[2]

PERIOD 1956	DIGESTER DISPLACEMENT (DAYS)	THICKENED SLUDGE FEED: % TOT. SOLIDS	% VOL. SOLIDS	LOADING LBS. VOL. SOLIDS/CU. FT/DAY	DIGESTER LIQUOR: pH	TEMP. F°	ALKALINITY	VOL. ACIDS	% TOT. SOLIDS	% VOL. SOLIDS	GAS - CU.FT/LB.VOL.MATTER: ADDED/DAY	DESTROYED/DAY	CU.FT.GAS/CU.FT. DIGESTER/DAY	% VOL.SOLIDS REDUCTION
AUG.	24	8.3	79	.17	7.1	94	2540	294	4.1	54.2	10.4	15.7	1.8	67.0
SEPT.	13.7	9.0	78	.31	7.2	93	2760	190	4.8	61.5	9.7	17.3	2.9	54.6
AVG.	18.8	8.7	78.5	.24			2650	242	4.5	57.8	10.0	16.5	2.3	60.8

NOTE: 1. 7' DIA. X 11' SIDE WALL DEPTH - THICKENER
2. DIGESTER VOLUME 426 CU.FT.
3. INCLUDES DATA FROM THE 18TH TO 31ST.

January 1, 1956 and July 11, 1956, average pumping figures for the Greenwich plant were 306 cu ft/MG of raw sewage. After the start of the pilot plant thickening, an average of 160 cu ft/MG was pumped to the digester. This reduction was accomplished by thickening half of the sludge flow from the primary Clarifiers.

Pilot digester studies were carried on simultaneously with the thickening tests. These studies resulted in satisfactory digestion at a digester displacement of 13.7 days, and a loading of 0.31 lbs volatile solids per cubic foot of digester per day.

During these studies, it was observed that the digester alkalinity did not exceed 3000 ppm which was approximately half that encountered at Middleboro. Alkalinity production at Greenwich was 0.033 lbs/lb of volatile matter added which is about one-third of that encountered at Middleboro, and lower than the figures reported for combined primary and activated sludges.

Gas production averaged 16.5 cu ft/lb volatile matter destroyed which is approximately 2.3 cu ft of gas/cu ft of digester capacity. It was also observed in this work that the reduction of volatile matter decreased with decreasing digester displacement time as noted by Rankin.(8) This reduction in percent volatile destruction is lowered not only because of the shorter biological detention time, but also because at the smaller detentions a greater portion of the well-mixed liquor is composed of freshly added raw sludge which is immediately short-circuited to the overflow of the digester. As an extreme example, in a three-day digester (completely mixed), one-third of the raw sludge and smaller percentages of less than the three-day detention material passes out to the overflow, and greatly decreases the possible destruction for a tank of such size.

During 1956, the Densludge Digestion System was designed into the Riverside, California low rate trickling filter plant which utilized a concrete dome tank equipped with Draft Tube Mixer for the primary digester, and a fixed cover tank for the secondary Digester. During the Summer of 1957, monthly operating data (Table 5), indicated that sludge to the digesters was being thickened to an average of 7.6% solids, while the primary digester was operating at an average displacement of 25.5 days at 0.13 lbs volatile solids/cu ft/day loading. At this rate, the average percent volatile destruction for the period was 47%. Gas production figures were not available due to insufficient gas metering equipment. In other words, the volume of gas was such that the gas meter could not handle the volume of gas produced, and flow was bypassed around the meter.

From the results of both pilot and full-scale demonstrations on various types of sludges, it has been demonstrated that thickening ahead of digestion is practical, and results in economic savings in the construction of sludge treatment facilities. Dust,(9) has reported that an estimated savings of $175,000 in the cost of the digester installation has resulted from use of prethickening at the new 30 MGD Biofiltration plant at Beaumont, Texas.

The recommended loadings for thickening and digestion using the Densludge Digestion System are as shown in Table 5A. It is of interest to note that these recommendations still provide approximately 22 days of detention time in the digester at volatile solids loading five - six times conventional.

Catalytic Reduction Process

The Catalytic Reduction Process was first detailed by Morgan,(3) during

TABLE 5

OPERATING DATA

DENSLUDGE DIGESTION SYSTEM

RIVERSIDE, CALIFORNIA

THICKENER:

PERIOD (1957)	DRY SOLIDS LOADING LBS/SQ.FT/DAY	OVERFLOW RATE GAL/SQ.FT/DAY	THICKENED SLUDGE TO DIGESTER		
			GPD	% SOL.	% VOL.
JUNE	6.8	680	13,300	7.9	71.2
JULY	6.6	680	13,700	7.4	70.6
AVG.	6.7	680	13,500	7.6	70.9

DIGESTER:

PERIOD (1957)	DISPLACEMENT: DAYS	LBS. VOL. SOLIDS PER CU.FT./DAY	DIGESTED SLUDGE TO STORAGE		% VOLATILE SOLID DESTRUCTION
			% SOLIDS	% VOL. SOLIDS	
JUNE	26	.13	4.9	56.2	48%
JULY	25	.13	5.4	56.2	46%
AVG.	25.5	.13	5.1	56.2	47%

DIGESTER SUPERNATANT RETURNED TO PLANT - NONE.

GAS PRODUCTION NOT MEASURED DUE TO INSUFFICIENT GAS METERING EQUIPMENT.

TABLE 5A

DENSLUDGE DIGESTION SYSTEM

RECOMMENDED LOADINGS

THICKENER:

TYPE OF TREATMENT	OVERFLOW RATE GAL/SQ.FT/DAY	LBS. SOLIDS/ SQ.FT./DAY	EXPECTED UNDERFLOW CONCENTRATION - % T.SOLIDS
PRIMARY SEDIMENTATION	800	20	12
HIGH RATE FILTER	"	12	8
LOW RATE FILTER	"	10	8
ACTIVATED SLUDGE	"	8	6

DIGESTER:

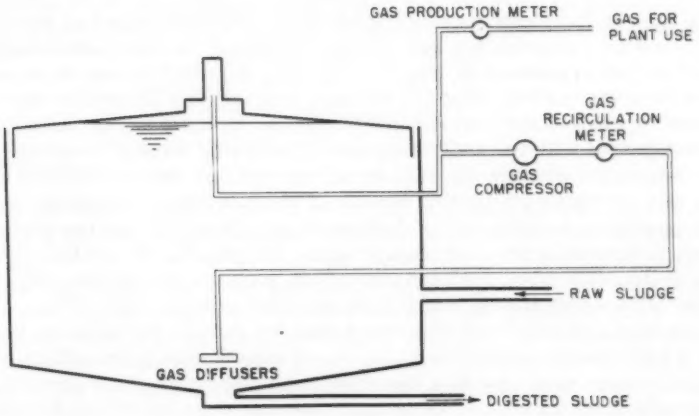
TYPE OF TREATMENT	% SOLIDS FEED	CU.FT/ CAPITA[1]	DIGESTER DETENTION (DAYS)
PRIMARY SEDIMENTATION	12	1/3	22
HIGH RATE FILTER	8	2/3	22
LOW RATE FILTER	8	5/6	22
ACTIVATED SLUDGE	6	1 1/3	22

NOTE:

1 DOES NOT INCLUDE STORAGE - THIS WILL BE DICTATED BY LOCAL CONDITIONS.

his pilot plant studies at Iowa City, Iowa Sewage Treatment Plant. The flow-sheet for the process as shown in Fig. 4, consisted of feeding raw sewage sludge direct from the primary Clarifier to the sludge digester. In the digester, mixing was accomplished by recirculation of sewage gas to the lower part of the digester through a central diffusion system. Sludge from the primary digester is then sent to a secondary digester in which a liquid separation is attained. Supernatant is returned to the head of the treatment plant.

Morgan showed in his pilot plant work that digester loading of 0.277 lbs of volatile solids/cu ft/day and digester detentions of 8.7 days were attainable.



CATALYTIC REDUCTION PROCESS

FIG. 4

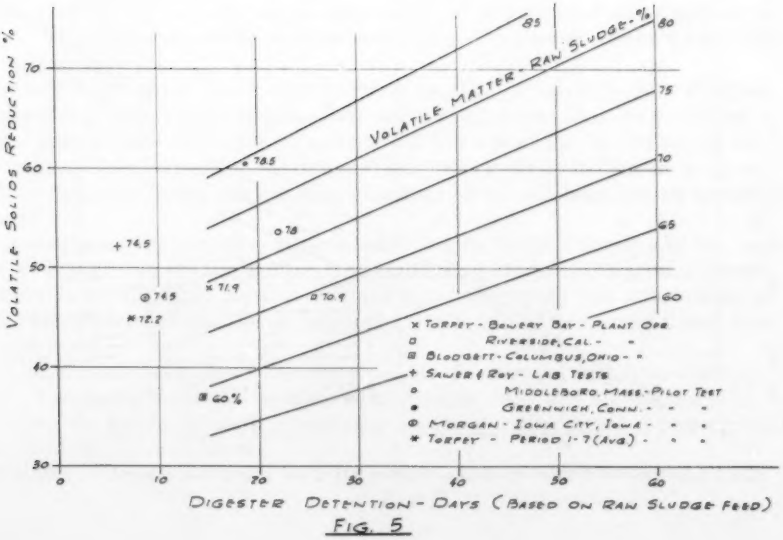

VOLATILE SOLIDS REDUCTION %
VOLATILE MATTER - RAW SLUDGE - %
DIGESTER DETENTION - DAYS (BASED ON RAW SLUDGE FEED)
X TORPEY - BOWERY BAY - PLANT OPR
RIVERSIDE, CAL -
BLODGETT - COLUMBUS, OHIO -
SAWER & ROY - LAB TESTS
MIDDLEBORO, MASS - PILOT TEST
GREENWICH, CONN. -
MORGAN - IOWA CITY, IOWA -
TORPEY - PERIOD 1-7 (AVG) -

FIG. 5

Blodgett in his studies on a full-scale digester showed that a volatile solids loading of 0.171 lbs/cu ft/day at a detention of 14.4 days was practical. However, the work at Columbus, Ohio was carried out on a low volatile sludge, and resulted in a volatile reduction of only 37%.

The authors do not have further data to cite for the system, however, the loading rates being recommended,[10] are 0.3 lbs of sludge solids added to the digester daily per cu ft of digester volume which will provide 8 to 13 days' digester detention.

General

The curves first reported by Rankin,[8] showing the effect of detention on volatile solids reduction for raw sludge containing various percentages of volatile solids are shown in Fig. 5. The data reported herein have also been plotted on these curves using the average percent volatile solids destruction reported by each of the various investigators. In most cases these data agree reasonably well with the reductions predicted using Rankin's curves.

To determine whether the rate of volatile matter destruction has changed, Fig. 6 was prepared by plotting pounds of volatile solids per cubic foot per day vs pounds of volatile solids destroyed per cubic foot per day incorporating the data indicated by the various symbols. The 45, 50, 55 and 60% volatile solids destruction lines are also shown. It is observed that the majority of the date falls within the 45 - 60% lines with the average near 52%.

It can be concluded from this curve that the rate of digestion up to a loading of 0.3 lb volatile solids/cu ft/day is not accelerating, but rather progressing at a uniform rate. As data becomes available on loadings above 0.3, it will be interesting to see where the break in the decrease in rate of digestion occurs. As detention periods are constantly decreased, it is to be expected that there will be a point where the percent raw sludge shortcircuiting to digested

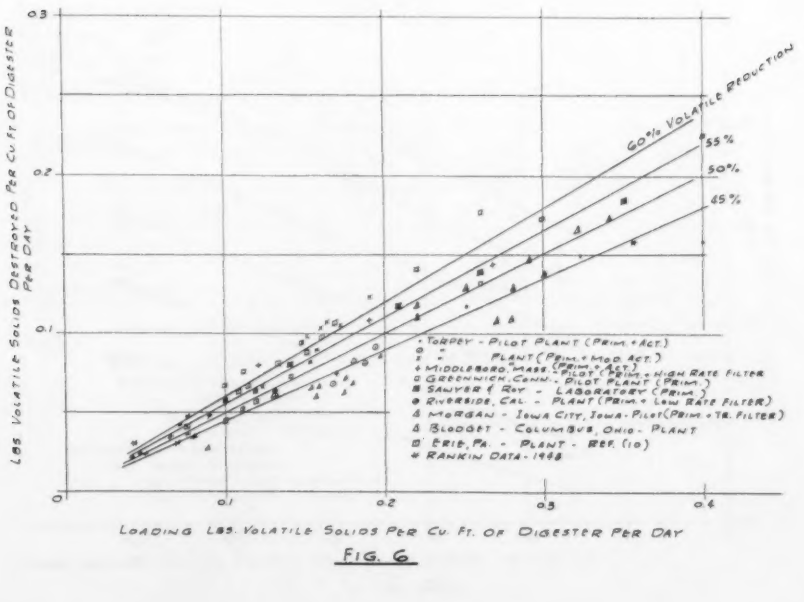

LBS VOLATILE SOLIDS DESTROYED PER CU FT OF DIGESTER PER DAY
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
60% VOLATILE REDUCTION
55%
50%
45%
• TORREY - PILOT PLANT (PRIM. + ACT.)
○ " - PLANT (PRIM. + MOD. ACT.)
+ MIDDLEBORO, MASS. (PRIM. + ACT.)
□ GREENWICH, CONN. - PILOT PLANT (PRIM.)
■ SANYER (ROT. - LABORATORY (PRIM.)
● RIVERSIDE, CAL. - PLANT (PRIM. + LOW RATE FILTER)
▲ MORGAN - IOWA CITY, IOWA - PILOT (PRIM. + TR. FILTER)
△ BLODGET - COLUMBUS, OHIO - PLANT
▣ ERIE, PA. - PLANT - REF. (10)
RANKIN DATA - 1948
LOADING LBS. VOLATILE SOLIDS PER CU. FT. OF DIGESTER PER DAY

FIG. 6

sludge overflow will show up as a greatly reduced percent volatile solids destruction.

These data show that great strides have been made in the art of sludge digestion in that higher digester loadings are possible with no decrease in percent volatile destruction over that normally encountered for conventional digestion.

As digester detentions are decreased, the question of "What is a digester sludge?" will undoubtedly arise. It has been put forth that a digested sludge is one which drains readily on a sand bed and is not offensive. This appears to be a satisfactory description at the present time. However, as new developments come forth recommending shorter digester detention times, some criteria or standard will have to be developed in order to adequately define the term.

Sludge Dewatering

Vacuum Filtration

Vacuum filters continue to be the generally accepted method of mechanically dewatering sludge. Advancements in the art during the first twenty-five years of application were not spectacular, however, a great deal of knowledge was gained regarding coagulants and filter media. In all of the early work, emphasis was placed on obtaining a filter cake of low moisture, and a low suspended solids in the filtrate. A great deal of work was done toward increasing the useful life of filter media. Development of elutriation of Genter,[11] decreased costs for coagulants by washing out alkalinity, and filter yields were increased due to the removal of some of the finer sludge particles.

More recently, the two major factors which have permitted advances in vacuum filtration are: (1) the willingness of design engineers and plant operators to permit higher suspended solids in the filtrate; (2) the greater variety of filter media now available to solve a particular problem.

Most of the filter media used until about 1950 were either cotton or flannel, and were generally of a weave which would produce a filtrate low in solids. After a short period of use, suspended solids of 200 ppm or less could be expected. This was considered desirable so as not to recycle fines to the sewage treatment process.

Table 6 shows filter performance for a number of plants which, with the exception of Winnipeg and Kalamazoo, were using either flannel or cotton media. These data show that in no case did the useful life of the media exceed 1000 hours. Unfortunately, the data did not include information on suspended solids in the filtrate but for the type of media reported, they can be assumed as being low.

Present practice is to pay little heed to solids in the filtrate and for certain types of sludge and media, suspended solids may exceed 2000 ppm. There probably is justification for this because percentagewise this solids loss is small, and where elutriation is practiced, the loss is often many times this amount.

Development of the CoilFilter by Komline-Sanderson, and Roto-Belt by Eimco, created interest in metallic media using stainless steel. Dorr-Oliver developed the stainless steel wedgewire media, but abandoned it commercially in favor of synthetic fabrics.

Synthetic fabrics include a long list, only a few of which have been field

tested and commercially applied. Filter leaf tests were run on a variety of media in order to select certain ones for field testing. Table 7 shows results for a few types of media which were tested in this manner, and Table 8 shows the specifications for this media. The principal value of the evaluation was simply to eliminate the media which were unsatisfactory initially, using wool 122 as control for each type of sludge tested. In all cases, it is felt that the filter cake yield was higher than could be expected in commercial operation as the tests were run under laboratory control using new media. Likewise, the suspended solids in the filtrate were higher than would be expected for media which has been used for some time.

Media must not only meet the filter leaf test but also must have a satisfactory useful life, be easily installed, free from stretch, and require a minimum of washing and maintenance.

By no means have all types on the market been thoroughly tested but from present knowledge, it is suggested that the following be considered for the specified applications.

Raw Primary

Saran	MS-900
Polyethylene	2200

Primary - Digested

Saran	903
Polymax	2712
Polyethylene	2200

Primary - Activated Digested

Dacron	Felt
Saran	915
Polyethylene	2200

TABLE VI

-VACUUM FILTER PERFORMANCE-

CITY	FILTER MAKE	SIZE	MEDIA TYPE	MEDIA LIFE	SLUDGE FEED TYPE	SLUDGE FEED % H_2O	CHEMICAL CaO	CHEMICAL Fe_2Cl_6	FILTER CAKE YIELD①	FILTER CAKE % MOIST.	SOURCE OF INFORMATION
MENASHA, WISC.	COMEY	8'-8"	FLANNEL	3 WEEKS	PRIM.-ACT. DIGESTED	92	YES	YES	3.4	66	POWER TABLE-WASTE ENG. JULY 1951
OKLA CITY, OKLA	OLIVER	5'-4"×10'	"	2 "	RAW	94	"	"	6.5	65	"
LANSING, MICH.	"	8'-8"	CANTON FLANNEL-8OZ.	400 TO 500 HRS.	PRIM.(ACT. DIGESTED	—	"	"	5	69-70	"
ARMY BASE NORFOLK, VA.	EIMCO	400 FT²	CANTON FLANNEL	150 TO 250 HRS.	—	90-93	"	"	6-7	70	"
MILWAUKEE, WISC.	OLIVER	11'-6"×14'	CANTON FLANNEL-8OZ.	900 TO 1000 HRS.	ACT.	98-99	—	"	2.5	82-85	"
MINN.-ST. PAUL	"	"	"	500 HRS.	RAW	91.3	YES	FERRI-FLOC	3.25	68.4	"
WASH., D.C.	COMEY	300 FT²	FLANNEL 12 OZ.	1000 HRS.	PRIM. DIG. ELUT.	93	—	3%	8	70-72	"
AUBURN, N.Y.	"	10'×10'	COTTON	2-3 MOS.	—	94	12%	6%	2.7	70	"
SAN DIEGO, CAL.	OLIVER	5'-4"×10' 8'×10'	FLANNEL	800 HRS.	PRIM. DIG. ELUT.	96	—	YES	1.5②	70	"
DEARBORN, MICH.	"	8'×12'	DUCK 8OZ.	600 HRS.	RAW CHEM. PREC	85-95	WASTE LIME	STEEL PICKLE	4	65	"
HARTFORD, CONN.	"	8'×14'	FLANNEL	800 HRS.	PRIM. DIG. ELUT.	94.9	—	1.83%	6.33	66.4	1953 REPORT
CLEVELAND, OHIO	"	5'-4"×10'	UNBLEACH. MUSLIN	176 HRS.	PRIM. DIG.	92	14.2%	3.08%	3.53	66.4	1954 "
WINNIPEG, MAN.	KOMLINE	10'×10'	COIL SPRING	—	PRIM. DIG. ELUT.	—	8.7%	1.7%	5.7	71.4	1956 "
KALAMAZOO, MICH.	"	10'×12'	"	—	PRIM. DIG.	90.4	13.3%	1.8%	3.24	76.7	1957 "

① LBS. DRY SOLIDS PER SQ. FT. OF FILTER AREA PER HR.
② RATE KEPT LOW TO BALANCE SLUDGE DRYER.

The Metropolitan Sanitary District of Greater Chicago,[12] at their West Sanitary Plant, experimented with a variety of filter cloths and methods of attachment to the filter drum. All of their filters had originally been designed with the media held in place with wire winding. Their experiments showed many advantages to panel construction and led to conversion of all their filters to the panel type. The media is held in place by acid resistant cord driven into dovetail mortises cut in the separator strips.

It had been feared that panel construction would shorten the media life because of direct contact of the scraper with the cloth, but experience showed the reverse to be true. Useful life increased an average of 44%, with 12, 13,

TABLE 7

FILTER LEAF TESTS ON VARIOUS TYPES MEDIA

MEDIA	WET SLUDGE		CHEMICAL		S.S. FILTRATE	FILTER CAKE	
	TYPE	% H_2O	CaO	$FeCl_3$	ppm.	YIELD[1]	% H_2O
WOOL 122	PRIM. DIG.	91.4	-	4.0%	742	11.2	76.2
DACRON 2115	"	"	-	"	550	11.2	71.9
" 2512	"	"	-	"	407	7.8	71.5
SARAN 903	"	"	-	"	1830	12.6	80.2
" 998	"	"	-	"	1140	12.5	75.8
" 915	"	"	-	"	430	6.8	70.8
POLYMAX 2712	"	"	-	"	1290	14.5	77.5
POLYETHYLENE 2200	"	"	-	"	410	12.8	73.7
WOOL 122	PRI.-ACT. DIG. ELUT.	95.1	-	5.0%	910	4.3	80.5
DACRON-FELT	"	"	-	"	206	4.2	76.9
POLYMAX 2712	"	"	-	"	0	3.8	77.2
POLYETHYLENE 2200	"	"	-	"	325	4.3	77.0
SARAN MS915	"	"	-	"	95	3.6	79.4

NOTE: - 1 LBS. DRY SOLIDS PER SQ.FT. PER HR. OF FILTER AREA.
2 LEAF TESTS BASED ON 3 MIN. CYCLE, 45 SEC. FORM, 90 SEC. DRY.

TABLE 8

FILTER MEDIA SPECIFICATIONS

MEDIA	WEAVE	COUNT	WT.-OZ./YD.
WOOL 122	NAPPED-TWILL	32 X 22	13.2
DACRON 2115	CHAIN	56 X 36	11.0
" 2512	TWILL	56 X 62	11.0
SARAN 903	PLAIN	44 X 44	5.4
POLYMAX 2712	"	110 X 39	7.5
POLYELHYLENE 2200	"	105 X 40	9.0
SARAN 998	SATIN	120 X 46	11.0
" 915	PLAIN	44 X 44	
" MS900	"	32 X 32	

and 14 - 15 ounce wool averaging 1900, 2400, and 2700 hours respectively.

The District also did work on evaluating characteristics of filter cloths and has tabulated the results in Shedden's paper.[12] It was concluded that 100% Dacron is the best material for their conditions, fulfilling all of their requirements, and giving a useful life of over 11,000 hours.

In 1954 the Minneapolis-St. Paul Sanitary District,[13] changed from Canton flannel to Saran media. They report the average useful life of the Saran as 5,743 hours with two of the cloths having exceeded 10,000 hours. There was a drastic decrease in the amount of chemicals required while still maintaining good moisture control with a cake which is eadily discharged. Frequency of washing of the media was decreased by 50%. Suspended solids in the filtrate rose from 110 to 2000 ppm, and total solids increased from 3500 to 4850 ppm.

Finn,[14] reports work done at Buffalo with nylon and Dynel filter cloths. Since adopting Dynel at an increase of first cost of 200%, the useful life has been increased 800%. Further economies have resulted from decreased labor and wire for filter windings.

Bargman et al,[15] call attention to the importance of the coefficient of fineness of sludge as being an important factor in sludge filtration. No doubt, this is one of the principal reasons it is so hard to predict results when designing vacuum filters for a particular job. For that reason, it may be necessary to select the proper media from experience after the plant is in operation.

The recent advancements in vacuum filtration of sewage sludge may be summarized as development of various types of media and the method of attachment to the filter drum.

While stainless steel media has received the most publicity, it has the disadvantage of high first cost and is expensive to replace. Often the continuous washing with large quantities of water offset any apparent savings in operating costs. Media openings are relatively large which is likely to result in excessive loss of solids to the filtrate for certain types of sludge which may have a high coefficient of fineness.

The wide variety of synthetic fabric media now available permits selection according to the particular problem. Long life expectancy and decrease in maintenance have resulted in lower operating costs. It has been shown at Chicago and other plants that panel attachment of the media has resulted in improved performance while increasing media life and decreasing cost of installation.

To date some work has been done with polymers to improve coagulation and increase filter yield. Bargman,[15] has shown the advantages of Separan at Los Angeles, resulting in 27.5% saving when using Separan and ferric chloride instead of only ferric chloride. He also describes experience with an unidentified polymer which produced spectacular results when used with a sludge otherwise difficult to coagulate.

Centrifuges

While dewatering sewage sludge using a centrifuge is not new, there has been some revival of interest. DeLaval centrifuges were installed at Findlay and Columbus, Ohio and Lansing, Michigan in the late 1930s. Tests were run prior to that on raw and digested sludges using the bowl-type centrifuge, and resulted in a commercial installation at Cedar Rapids, Iowa.

There was a revival of interest in centrifuges for digested sludge when Jenks,[16] installed one at Daly City. It was realized that a higher percentage of the solids would be lost with the centrate, but this was permissible for the particular installation. However, if centrifuges are to receive general acceptance, ways must be found to capture a greater percentage of the solids.

Direct Thermal Reduction

Pilot plant work at Chicago on the Zimmermann Process,[17] has recently been announced. It is a wet oxidation process, and if successful, would eliminate the dewatering step as it is now understood. The sludge, after thickening, goes directly to the process where the greater part of the organic matter is reduced to the gaseous state.

The Atomized Suspension Technique,[18] as developed by the Pulp and Paper Research Institute of Canada has been proposed for treating sewage sludge. It is described as being a method for physical, thermal separation of dissolved or suspended solids from liquids and subsequent chemical treatment of those solids by means of gas-solid reactions in a continuous operation.

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20 YEARS OF SEWAGE SLUDGE BURNING AT BARBERTON, OHIO

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ABSTRACT

Experiences using incineration as a means of disposing of raw sewage sludge cake from a domestic sewage treatment plant are discussed. Included in the discussion is a cost analysis and a breakdown of the various properties of the sewage and the final product.

1920 found the City of Barberton, Ohio, with a new and then modern Sewage Treatment Plant of the Imhoff Type with open sludge drying beds. The facility was estimated to have a useful 20 year life. This placed the city in an enviable position in the area.

Soon after starting operations high water flooded the plant. The City grew, with a residential development near the plant. A large elementary school was built within 1/4 mile. The resultant complaints of fly and odor nuisances caused the plant to be abandoned within months after commencing operations. Needless to say, much criticism was leveled in all directions. Barberton was without sewage treatment from that time until 1938.

Following the lessons of 1920 a new plant designed in 1936 by Barstow & LeFeber of Akron, Ohio, was built and placed in operation early in 1938. Litigation and condemnation was necessary to secure a site at higher elevations and at considerable distance from potential residential areas. Some nearby area was then zoned industrial as is all surrounding areas now. Deed restrictions greatly hampered methods of operation. A chemical precipitation plant was required to comply with the restrictions.

The Barberton sewerage system is a separate system. The wastes handled at the plant are basically domestic.

Table I shows typical analysis.

Ferric Chloride and Lime was used in the primary treatment plant, with a magnetite filter for final effluent clarification. Design capacity was 3.5 MDG

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1. Supt. of Utilities, Barberton, Ohio.

with 65% B.O.D. and 65% suspended solids removal. This met the standard at that time set by the Department of Health of the State of Ohio. Present State standards require 90% B.O.D. 90% suspended solids removal. The new plant is being designed on that basis.

Numerous changes were made over the years. Pre-settling tanks and grit collectors have been added. Mechanical flocculation with the addition of alum has been substituted for Ferric Chloride and Lime.

The new plant being designed by Burgess & Niple, Civil & Sanitary Engineers of Columbus, Ohio, is to be of the activated sludge type. The only piece of equipment not being abandoned or converted is the sludge disposal unit. Present plans call for duplicating the incineration and filtering equipment as the need arises, to increase capacities.

Sludge incineration was selected by the City in 1937 because of the following circumstances:

1. The problems of the 1920 plant,
2. The County Health Department would not approve of open sludge drying beds and lagoons out in the County,
3. Deed restrictions at the plant site,
4. Last, and perhaps the most cogent, the attitude of the General Public toward drying beds and lagooning. This attitude had been brought about by existing conditions, since corrected, in neighboring communities using beds and lagooning methods for disposal.

The 1937 plant was designed to burn raw sludge, as is the proposed new plant. We find there is a real savings in cost by burning raw sludge. The cost of building and operating sludge digesting equipment is eliminated. The additional cost for raw sludge storage space is much less than like digestion space. By burning raw sludge we find that its heat value is sufficient to

TABLE I

INFLUENT SEWAGE ANALYSES

Barberton, Ohio

Year	BOD ppm	Suspended solids ppm	Total solids ppm	Settleable solids cc/l	pH	Average daily Flow M.G.
1948	178	160	662	3.7	7.4	2.72
1949	194	164	676	4.1	7.3	2.76
1950	168	141	640	3.7	7.5	2.94
1951	180	160	796	3.9	7.4	3.03
1952	194	180	705	3.4	7.3	2.82
1953	202	224	753	4.2	7.5	2.94
1954	210	256	817	4.6	7.4	3.52
1955	163	171	725	3.6	7.3	2.93
1956	174	188	756	3.8	7.3	3.18
1957	162	168	774	3.5	7.3	3.04

support the drying and combustion process without extraneous fuel, once the heating-up cycle is completed.

Table II gives typical sludge and filter cake analysis.

The sludge disposal equipment comprises two 100 sq. ft. continuous vacuum filters and appurtenant ferric chloride and lime feeders. Sludge conditioning is accomplished in a continuous flow-thru tank.

Average chemical dosages and typical filter cake production are shown in Table III.

The sludge incinerator consists of a steel shell, 10'-9" in diameter,

TABLE II

CHARACTER OF SLUDGE

Barberton, Ohio

Year	Undigested Sludge Dry Solids %	Undigested Sludge Volatiles %	Filter Cake Dry Solids %	Filter Cake Loss on ignition %
1948	6.7	72.7	30.6	64.6
1949	6.6	72.5	30.1	63.1
1950	7.5	72.7	30.7	63.5
1951	8.0	71.3	30.3	63.3
1952	8.4	70.4	31.2	62.3
1953	7.5	72.3	30.6	61.2
1954	8.8	68.2	31.1	57.8
1955	7.6	70.8	29.2	61.2
1956	7.0	68.6	28.1	62.3

During the years in the above table, the calorific value of ash and moisture-free solids have varied between 10,500 and 11,600 Btu per lb; the average would probably be about 11,000 Btu per pound.

TABLE III

CHEMICAL FEED &
FILTER CAKE PRODUCTION

Barberton, Ohio

Year	$FeCl_3$ %	CaO %	Filter rate dry solids lb./sq.ft./hr.	Sludge cake lb./hr.	Dry solids burned tons/year	Burning time hr./yr.
1948	5.2	8.7	6.00	1527	445	
1949	4.5	7.6	5.38	1781	404	1507
1950	4.9	7.5	5.65	1840	522	1847
1951	5.1	7.8	5.82	1911	568	1962
1952	5.1	7.3	6.17	1764	548	1989
1953	5.5	8.4	6.13	1928	688	2246
1954	4.2	7.5	6.18	1968	737	2410
1955	3.0	8.2	5.84	1945	640	2255
1956	3.2	9.4	5.34	1934	240	876

surrounding six refractory hearths and a central rotating shaft to which rabble arms are attached.

The hearths are constructed of high heat duty fire brick and special refractory shapes. The upper, or No. 1 hearth has a central circular opening through which sludge passes to the second hearth. The upper hearth is called an in-feed hearth and the next lower hearth an out-feed hearth. The latter type have ports, or drop-holes around the periphery of the hearth through which sludge falls to the next lower, or in-feed hearth.

One access door with observation ports are provided at each hearth level.

Since the furnace operates at high temperatures, above 1400° F in the combustion zone, the central shaft and rabble arms are effectively cooled by air supplied in regulated quantity and pressure from a blower discharging air into a housing at the bottom of the shaft.

The central shaft is an iron column cast in sections. The sections enclosed by the furnace have a tubular inner column called the "cold air tube". The annular space between the inner tube and the outer wall of the shaft exposed to furnace heat, serves as a passageway for hot air and is referred to as the "hot air compartment".

The shaft revolves upon hardened steel buttons set within a step bearing and is supported at the top by a simple bearing. It is motor driven through means permitting adjustment of speeds.

Two or more rabble arms are connected to machined arm sockets in the shaft at each hearth. Each rabble arm is constructed with a central tube for the purpose of conducting air from the "cold air tube" to the extreme end of the rabble arm, thence back through an outer air space in the arm to the shaft and through passages opening into the hot air compartment from which it may be discharged to atmosphere or returned to the bottom hearth of the furnace as preheated air, for combustion purposes.

Rabble arms and teeth used in the high temperature zones are cast of chrome-nickel-iron. Rabble teeth are cast with a dovetail button that loosely fits the dovetail groove along the underside of the rabble arm and designed so that when all teeth are in place, each tooth is automatically set at its correct angle upon the arm.

The center shaft and cooling air fan are driven by 2-h.p. motors. Together with the ash pump which is driven by a 5-h.p. motor that operates about 4 minutes per hour, the total connected electrical load is 9 h.p. consuming an average of about 3 kwh.

The burning process in a multiple hearth furnace progresses continuously through the drying, combustion, and cooling zones of the unit. Sludge enters the top hearth and is rabbled across each hearth to the ash outlet in the bottom hearth. Rabbling not only moves the sludge through the furnace, but in doing so provides a form of continuous and gentle stoking that assures complete exposure to heat of all the sludge particles, resulting in complete destruction of all putrescible organic matter.

The practice had been to store sufficient sludge to provide a maximum of continuous 24 hour per day operation. Because of recent changes in working conditions, the furnace is shut down over week-ends. Natural gas is used for fuel. Since 1938 the furnace has gone through approximately 168 heating up, burning, and cooling-down cycles, or an average of once every 6 weeks. A 36-hour heating up period is generally employed to bring the furnace up to operating temperatures from room temperature. A like cooling off period following operation is used. This procedure is followed only when the furnace is to be out of service longer than a week.

During a typical 8-day continuous run of 182 hours, the operating records show the feed to the furnace averaged 1980 lb. of 65% moisture filter cake per hour. The minimum hourly rate was 1750 lb. and the maximum was 2190 lb., or about 130% of original rating.

Since the total quantity of sludge burned during the period was approximately 360,125 lb., wet, or 110,340 lb., moisture-free, the total fuel consumption per ton of sludge burned, averaged 315 cu. ft. of gas at a cost of 20.6 cents per ton of wet filter cake equal to about 71 cents per ton of dry solids.

During the foregoing operations, the ash pump operated approximately 4 minutes per hour, or a total of 15.67 hours out of 182 hours. The total electrical consumption was computed to be 546 kwh, or 9.9 kwh/ton of dry solids.

Temperatures during the above operation averaged about 1500° F in the combustion zone, with gases going to the chimney averaging 490° F.

Undigested sludge, fed to the furnace at fairly uniform rates, and burning without fuel, maintains quite uniform temperatures throughout the furnace. This condition requires almost no personal attention to furnace operation.

Table IV illustrates our meaning of the statement regarding uniform conditions and personal supervision.

Table IV illustrates a typical start up after a 36 hour heating up period. Filter cake solids averaged 31.7%; Volatile solids, 49.6%.

Incinerator ash is disposed of by quenching and pumping to a lagoon.

TABLE IV

FURNACE OPERATION

Barberton, Ohio

August 18-19, 1958

Hour	Gas Outlet	Temperatures Hearths 2	4	6	Filter cake lb./hr.
12 N	1000	1090	1010	760	
1 PM	1000	1100	1000	780	1950
2 PM	1020	1120	1000	780	1998
3 PM	1000	1340	1240	740	1950
4 PM	1020	1420	1140	760	1974
5 PM	980	1460	1160	770	1950
6 PM	960	1440	1220	660	1958
7 PM	970	1460	1240	640	1918
8 PM	890	1320	1290	600	1958
9 PM	880	1470	1260	570	1910
10 PM	900	1320	1200	560	1918
11 PM	890	1360	1190	480	1966
12 PM	860	1120	1320	400	1934
1 AM	1000	1360	1380	470	1942
2 AM	1010	1380	1400	480	1942
3 AM	1080	1400	1380	500	1918
4 AM	1060	1360	1340	480	1934
5 AM	1000	1360	1300	480	1926
6 AM	980	1300	1320	460	1980
7 AM	1060	1390	1380	480	1980
8 AM	980	1400	1370	500	2014
9 AM	860	1330	1380	520	1982
10 AM	840	1360	1380	540	2006
11 AM	880	1340	1360	480	2014

Results have been very satisfactory. Slurry pumping eliminates the dust and fly ash problem entirely. Maintenance costs on the pump and appurtenances have been limited to rubber linings.

After 20 years of operation the furnace was relined and the flue system simplified. The original installation included a fly ash collector, which was found to be unnecessary and was eliminated. The feeder was changed from a rotary drum type to double flap gates, thereby eliminating an additional motor. The operation has been made easier and simpler with these modifications. The gases discharged from our chimney are remarkably free of smoke and significant fly ash. We have never had an odor problem.

Cost of the incinerator operation as such is difficult to arrive at. Two men are required to operate the treatment plant. These same two people also operate the incineration equipment with no additional help. If the sludge disposal operation including filtering and burning are considered together, then one man is required. Part of each hour is spent by one man, observing, adjusting and pumping incinerator ash on the incinerator.

During the period 1949 through 1955 the furnace operated a total of 14,216 hours, and burned 4,347 tons of dry filter cake, equal to 14,336.1 tons of wet cake at an average of 69.68% moisture. During the same seven years, the total cost of gas and electricity was $3,645.72. Total plant labor was $163,962.94. The furnace ran 14,216 hours out of a total 61,344 hours, or 23.17% of the time. 23.17% of $163,962.94 = $37,990.21, or the total cost of plant labor during the furnace operating hours. If we can assume the operators devoted one-third of their time to the furnace, the total cost of labor plus gas and power was $16,309.49.

$$\$16,309.40 \div 4,347 \text{ tons d.s.} = \$3.75 \text{ per ton}$$
$$\text{and, } \$16,309.49 \div 14,336.1 = \$1.14 \text{ per ton of filter cake.}$$

Now, if we add $7,000 ($1000/yr.) for maintenance, the costs are:

$$\$23,309.49 \div 4,347 = \$5.36/\text{ton dry solids, or}$$
$$\$1.63 \text{ per ton of filter cake.}$$

Table V gives some estimated costs of fuel, power, chemicals and labor required.

The detailed break-down of maintenance costs available from larger plants is impossible to arrive at, due to the integrated operation in Barberton. Maintenance costs on the incinerator have not been excessive. Prior to relining the furnace, minor hearth repairs were periodically made, as required for good maintenance. The relining job cost approximately $16,000.00. This also included the new feeder, elimination of fly ash collector and new flue connections complete with damper. Over the 20 year period, the average total maintenance cost has been less than $1,000 per year or approximately $0.56 per ton of wet filter cake burned. Weighed against other sewage treatment equipment at the plant, this is very good. In view of the numerous heating cycles we feel that it has been an economical operation.

In conclusion we feel that "Sludge Incineration selected by the City in 1937" was a wise decision. Incineration in the multiple hearth is a clean, efficient, and economical method of sewage sludge disposal that might well apply to many other cities in the 25,000 to 50,000 population class.

1. The capital outlay for the incineration equipment was less than that required for digestion and sludge drying equipment.

2. Sludge disposal is not hampered by weather and climatic conditions.
3. Any insect and odor problem of other types treatment are eliminated.
4. Smaller plant site was required.
5. Less labor is required for sludge handling.
6. Any health hazard from open beds and sludge piles were eliminated.

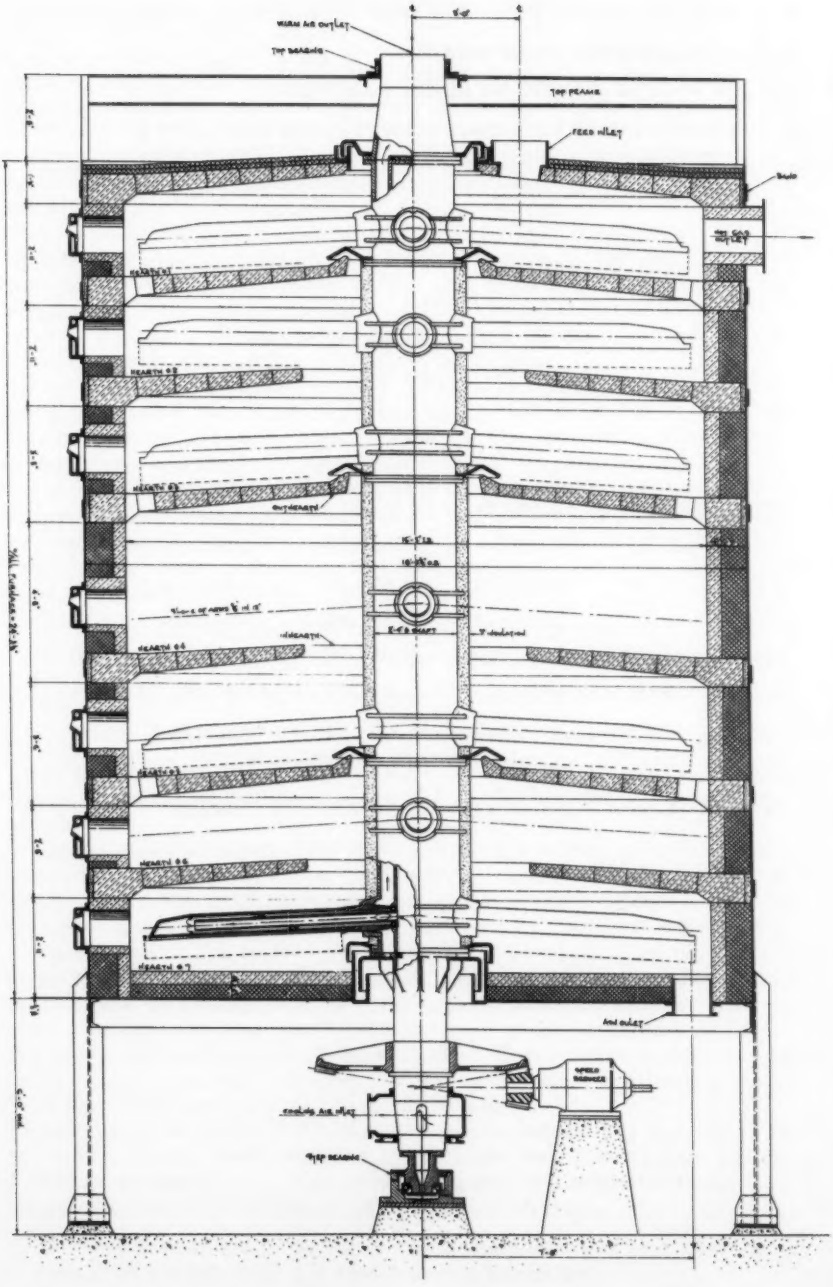
Note: Furnace description and cuts were taken from "Sludge Incineration" Mark B. Owen, M. ASCE (Proc. Paper 1172) February 1957.

TABLE V

ANNUAL COST OF SEWAGE TREATMENT

Barberton, Ohio

Year	Total per M.G.	Labor	Chemicals for sludge conditioning	Furnace Operation Natural gas	Electric power
1949	$24.41	$18,498.80	$1,853.42	$268.40	$50.00
1950	21.87	16,782.41	2,523.06	288.50	61.00
1951	26.41	22,235.81	4,194.29	403.10	67.00
1952	30.14	22,159.01	4,200.25	397.71	69.00
1953	38.51	27,997.37	4,632.59	471.18	81.50
1954	31.92	27,366.27	4,443.69	410.56	90.75
1955	40.52	28,953.27	3,922.74	902.52	84.50
1956	35.61	28,958.35	1,589.04	568.52	30.40


TOP FRAME
FEED INLET
HEARTH
HEARTH
HEARTH

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

EVALUATION OF EDUCATION AND RESEARCH IN SOLID WASTES ENGINEERING TWENTY-FOURTH REPORT OF THE COMMITTEE ON SANITARY ENGINEERING RESEARCH OF THE SANITARY ENGINEERING DIVISION

ABSTRACT

A survey was completed of the extent of current solid wastes engineering, education, and research at some sixty American universities and colleges. The results of replies from some 95% of those contacted and a critical evaluation of additional solid waste engineering education needs are presented.

INTRODUCTION

In 1957, 481 cities of over 25,000 population in the United States spent a total of $394,187,000* for the collection and disposal of solid wastes. This represents only municipal funds expended and does not include payments made by individuals to private collectors in many cities such as San Francisco, California, and Portland, Oregon.

By way of comparison, this same group of cities in 1957 spent $426,139,000* for sewerage and sewage treatment which includes $202,534,000 for capital outlay.

In New York City in 1957, $85,831,000* was spent on solid wastes collection and disposal, including street cleaning, while sewers and sewage treatment cost $28,442,000 including $18,318,000 for capital outlay.

In New York City in 1957, $85,831,000* was spent on solid wastes collection and disposal, including street cleaning, while sewers and sewage treatment cost $28,442,000 including $18,318,000 for capital outlay.

These comparisons serve to point out the magnitude of the solid wastes problem in our cities on a strictly dollar and cents basis. When any expenditure in our cities reaches these proportions, it deserves some study with an

Note: Discussion open until April 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2248 is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. SA 6, November, 1959.

* From Compendium of City Government Finances in 1957, U. S. Department of Commerce, Bureau of the Census.

objective of reducing these costs by finding and applying more efficient methods of operation.

What is being done today in the engineering profession toward solving the solid waste collection and disposal problem? To what extent is solid wastes engineering being taught in our schools. Are our colleges and universities doing research in this field?

The answers to these basic questions was the object of a questionnaire survey during December 1958 by the Sanitary Engineering Research Committee, Solid Wastes Engineering Section.

Questionnaires were sent to sixty-three colleges and universities in the United States offering sanitary engineering training. Replies were received from sixty schools representing over 95% of those contacted.

Summary of Survey Results

Instruction

Only two schools reported that a formal course was offered on solid wastes engineering, one at the undergraduate level and one graduate course.

The subject of solid wastes was included as part of another course in forty-eight schools. Of these, 41 offered the subject as part of one undergraduate course, one as part of another graduate course, four as part of two undergraduate courses, and two as part of one undergraduate course and one graduate course. Solid waste engineering was not offered at all in ten of the schools reporting.

The amount of time devoted to solid wastes as a part of other course ranged from 2% to 40%. Forty-one schools reported that 10% or less of the course was devoted to this subject and nine schools reported that over 10% of the course time was on solid wastes engineering.

Research

Three schools reported that research has been done in the past on solid wastes collection and disposal.

Five schools now have research projects in progress. Four of these deal with the disposal of municipal refuse and one with the disposal of fissionable wastes.

Research was reported to be planned at two schools.

No research is in progress or is planned in forty-seven of the reporting institutions.

Text and References

The most widely used text on solid wastes collection and disposal is Ehlers and Steel's Municipal and Rural Sanitation which is used in nine schools. Publications of the U. S. Public Health Service are used in five schools and Babbitt's Engineering in Public Health in four schools. Other tests reported to be used are University of California's bulletins, Hopkins and Schulze' The Practice of Sanitation, War Department T. M. 5-634, Abbetts' American Civil Engineering Practice, Volume II, Frobisher's Fundamentals of Bacteriology and several periodicals.

Discussion

The Solid Wastes Engineering Section Members have undertaken to discuss the following questions:

1. Should solid wastes engineering be offered as an undergraduate subject in view of the now crowded curricula in sanitary engineering?
2. Should it be offered as a graduate course in more schools?
3. If courses in solid wastes engineering are offered would students be interested in studying what is commonly thought of as "garbage collection?"
4. Would graduate research projects interest more students than formal text-book courses?
5. Is on-the-job training, such as is now practiced, the best method for a person to learn the game?

F. R. Bowerman[a]

1. Solid wastes engineering should be offered as an undergraduate subject in sanitary engineering in order that the student who cannot or does not plan to take graduate work may have some familiarization with the subject. Although it is a desirable goal that all sanitary engineering graduates be exposed to at least five years of college training, one of the facts of life is that this is not presently achieved that that many young men are entering engineering practice without specialized graduate courses. Only the brief exposure that might result from a single course at the undergraduate level would still enable such a person to more confidently and competently approach future problems which he might encounter in the field of solid waste engineering. Having taught some seven years at the University of Southern California at the undergraduate level in the field of sanitary engineering, I can say from experience that sufficient solid waste engineering can be incorporated into courses which are now predominantly sewerage courses to be of benefit to the student.

2. Specific advanced courses in solid waste engineering should be offered as graduate courses at all schools proposing to offer a sanitary engineering option.

3. "Garbage Collection" as a separate object of study should not be offered, but the sanitary engineering student should be required to study the several methods of collection involved in solid waste disposal.

4. Graduate research projects in solid wastes engineering would not substitute for normal textbook courses, but should be used as supplemental, not substitutional.

5. On-the-job training in the field of solid wastes engineering is now practiced largely because there is no alternative means by which an engineer can develop skill in that field. Unfortunately, on-the-job training tends to perpetuate inappropriate and uneconomical procedures and is, therefore, only desireable if it can be preceded by formal academic training which enables the engineer to properly evaluate the on-the-job experience.

a. Assistant Chief Engineer, L. A. County Sanitation Districts.

John C. Merrell, Jr.[b]

1. Solid wastes engineering should not be offered as a full course until the engineering phases have been developed to create a demand for trained personnel.

2. The development of graduate courses should be offered where concurrent research makes the course attractive and productive of increased knowledge.

3. Students will enter this field when the challenge of gaining engineering knowledge for the improvement of their professional opportunities exists.

4. Graduate research projects normally interest fewer students than undergraduate courses but the numbers of students usually follow the demand and at present this demand does not seem to exist.

5. On-the-job training is satisfactory but very limited for the type of engineering and research necessary to develop the new approaches necessary in the field of solid wastes collection and disposal.

Research services are customarily employed to develop new methods, procedures and devices that will provide more economical solutions or novel approaches for the subject problems. When this research is provided at universities, graduate training is usually involved. Undergraduate training does not usually follow until the employment possibilities in that field require this education. The lack of a solid wastes engineering course at the undergraduate levels results from the absence of employment opportunities, the limited research at the graduate level and a lack of interest in bringing the problems to the research field by the managers of the solid wastes collection and disposal.

The costs in the field of "garbage collection" consists primarily of land, manpower and transportation and vested interests tend to keep this status quo. Some small improvements result from time to time through on the job suggestions and developments and through patents or improvements to equipment. The impetus for developing the research and engineering phases of solid wastes collection and disposal will have to come from the field or be sponsored by government.

Ralph Stone[c]

1. Solid wastes engineering is a specialized field similar to highway engineering or sewage treatment. The large sums of money currently spent and the basic importance to health and aesthetics of solid wastes engineering practice is indicative of the great need for broadening the undergraduate curriculum to provide basic training in this field. There appears to be a real lack of professional interest in research and development projects to reduce costs and improve operating standards. Why is this? Perhaps the answer lies in the fact that solid wastes engineering is generally a monopoly activity performed normally by a single governmental agency or under contract by a private operator. Only recently has there been enough basic study to indicate the relative importance of good refuse handling to the community.

b. Special Assistant, U. S. Eleventh Naval District, Public Works Office, San Diego, California.

c. Consulting Engineering, Ralph Stone & Co., Beverly Hills, California.

2. Graduate courses in solid wastes engineering are just as important as similar specialized instruction in water or sewerage.

3. Garbage collection at present does not warrant a special course of study.

4. Graduate research projects are not a substitute for formal textbook studies. The researcher is involved in detailed investigations of new frontiers of knowledge. The graduate courses allow a rigorous presentation of known principles and accepted practice.

5. On-the-job training is a poor background for broad professional development. It can represent the difference between a continuation of routine practice and the breakthrough to higher standards of solid waste disposal.

Other Comments

Governmental agencies are directly or indirectly the primary group concerned with lowering costs and improving standards in solid wastes engineering. Hence, it would appear that these governmental agencies would be leaders in promoting funds for research in the universities. The support of research and the training of personnel would lead to the "feedback" of further activities in the waste field. Undergraduate, graduate, and post-professional training would then be worthy of our modern economy. The present survey indicates that recent scientific developments in nuclear energy and air pollution coupled with wide scale suburban development are helping to create widespread challenges for solid wastes engineering.

Leo Weaver[d]

The law of supply and demand is basic to a free economy, whether it be in materials or professional personnel. To take the engineering schools to task for not placing in their curricula or their research programs more emphasis on solid wastes engineering is akin to condemning the municipal sanitation official for not reclaiming a community's solid wastes even though there be no market for the reclaimed product. At this time, it is not a question of the good or bad aspects of the number of universities which recognize the engineering potentials in solid wastes collection and disposal problems. What we should be most concerned about is the need for one or two universities to be setting a pioneering pattern in this field. After all, little more than ten years has transpired since the U. S. Public Health Service assigned one of their regular Sanitary Engineering officers to work on the overall problem and little more than two years since that same organization chose to recognize the community refuse sanitation activity as worthy of administrative entity status.

There has been a second fundamental factor which merits consideration, i.e. lack of program instructional tools. It has been thirty-eight years since Herring and Greeley published their excellent text Municipal Refuse Collection and Disposal. In 1941 the American Public Works Association published Refuse Collection Practice, a volume out of print since 1946. Only last year was the revised second edition made available. A similar volume on "disposal" is due for publication in 1960. Manuals of Practice on Sanitary Landfill and Incineration are currently in the publication channels of ASCE. Thus,

d. Assistant Director, American Public Works Association, Chicago, Illinois.

the general tools of engineering instruction comparable to other fields of sanitary engineering are only now becoming available.

Finally, with the exception of incineration and reclamation or salvage works, it has been only recently that the investment in equipment, plant, and materials seemingly has warranted engineering attention in most cities. It was only six years ago that one large city retired its last horse and wagon garbage conveyance.

What does this all mean? Simply that we are hardly past the nineteenth century "Lawrence Experiment Station" stage of development in the field of solid waste disposal and must look ahead, not back. For the need for solid wastes engineering is now emerging from its long dormancy to command significant attention in the coming decade.

The role of the U. S. Public Health Service in the development of this field in its importance to the healthful community environment is one of considerable significance. The PHS has given valuable technical assistance and cooperated closely with the APWA and the ASCE subsection on solid wastes engineering in developing basic engineering techniques and source reference and instructional materials. The institution of significant programs in this phase of engineering at one or more pilot universities at the graduate level, encouragement of key research programs and assistance in training key state health department and local public works engineering personnel remain substantially to be accomplished. All of these are important to the orderly development and application of modern engineering know-how to community solid wastes problems on a broad scale. When it is conclusively demonstrated that engineering know-how can mean important differences in the efficiency and thus the economics of community refuse disposal systems, it will not be difficult to influence communities to employ such services nor to prevail upon universities to include courses of instruction which would help qualify civil engineers to provide such services.

Edward R. Williams[e]

Solid wastes engineering, alias refuse collection and disposal, is accepted by the American Society of Civil Engineers as a responsibility of sanitary engineers. Since the practice of Sanitary engineering is defined to include solid wastes engineering, it seems reasonable to expect that college curricula for sanitary engineers should contain at least an introduction in this area of practice. The minimum instruction should provide the graduate with a fundamental knowledge of equipment, collection and disposal methods, terminology, associated disease vectors, waste quantities and costs. Whether solid wastes engineering is offered as a separate course or part of another course is not so important. What is important is that it be offered and required of all undergraduate sanitary engineering students.

The 1957 Conference on Education, Training and Utilization of Sanitary Engineers, National Academy of Sciences, National Research Council, recommended a one-year program leading to a Masters of Science degree in sanitary engineering. Solid wastes disposal was included in the recommended electives.

This survey points out that currently only one institution offers a formal graduate course in solid wastes engineering. Adding one or more graduate

e. Sr. Sanitary Engineer, U. S. Public Health Service, Washington, D. C.

courses on this subject in several more schools, well distributed geographically, would present the interested student with a choice of school and location; certainly a desirable situation in any field of education.

Schools which adopt formal course work in solid wastes engineering should endeavor to parallel the text-book teaching with research projects financed by manufacturers and governmental agencies.

There is not substitute for on-the-job training in this "game" and it is certainly not peculiar in this respect. Similar situations exist in many phases of public works and engineering. The object of education should be to provide engineering fundamentals and research methods. The expected result should be more efficient, sanitary, and economical solid wastes collection and disposal through the engineering approach.

CONCLUSIONS

The survey data indicate that at present most engineering colleges have a limited solid wastes education and research program. There is need for expanded curriculum, textbook and research resources. The stimulus including financial support for improved academic facilities should logically be provided by the major beneficiaries — the governmental agencies concerned with solid wastes.

Credit

This research report is one of a series of professional contributions by the Committee on Sanitary Engineering Research, with special acknowledgment to the universities and others that made data available.

	E. R. Hendrickson)	Air Pollution
	W. T. Ingram)	
	M. A. Churchill	Stream Pollution
	R. W. Bogan	Sewage
	C. H. Hull	Water
	H. A. Faber	Public Health
	R. Stone	Solid Wastes
Chairman,	N. L. Nemerow	Industrial Wastes
	Frank Bowerman)	
	John Merrell, Jr.)	
	Leo Weaver)	Solid Wastes Engineering
	Edward R. Williams*)	Section
Head,	Ralph Stone)	

* Primary responsibility for the survey and preparation of the manuscript.

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

METROPOLITAN SECTION, ASCE, SEMINAR ON SANITARY ENGINEERING RESEARCH

Twenty-fifth Progress Report of the Committee on Sanitary Engineering Research of the Sanitary Engineering Division

ABSTRACT

The paper reviews the discussion held at a Seminar at Manhattan College, New York City, on June 5, 1959 relating to the problems of Sanitary Engineering Research and ways and means of promoting both finances and quality students in the field.

Mr. Dappert pointed out the difficulties his state agency had to overcome in order to participate and sponsor important research projects. He commended upon the duck waste problem on Long Island as an illustration of his state agency's research contribution. He also enumerated the several significant projects his agency is currently sponsoring and supporting - with the aid of federal funds under Public Law 660 - at Manhattan College, New York University, Cornell University, Syracuse University, and elsewhere within the State of New York. He showed that it is possible and desirable for a state pollution control agency to participate in research of special interest to the state.

Preliminary Remarks by Presiding Chairman

Every operation of mankind has a lifeline without which the operation will eventually cease to exist. Sanitary Engineering is no exception to this ancient and proven truth. The lifeline of Sanitary Engineering is research. New fundamentals and developments can vitalize our relatively stagnant field.

Your Sanitary Engineering Research Committee is attempting to make a significant contribution in this matter. The Committee is composed of eight recognized Section Heads in the several areas of Sanitary Engineering.

Note: Discussion open until April 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2249 is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. SA 6, November, 1959.

Ralph Stone in Beverly Hills, California is in charge of Solid Wastes Disposal, Dick Bogan at the University of Washington is heading the Sewage Section; C. H. Hull at Johns Hopkins University heads the Water Section; both Bill Ingram of New York University and E. R. Hendrickson share the responsibilities of the Air Pollution Section; Harry Faber directs the activities in the Public Health Section; and your speaker heads the Industrial Wastes Section. These men on your Committee are concerned with all matters involving research but concentrate upon reporting and evaluating current projects and stimulating new ones. Let me urge you to contact any of these men for assistance or to give them ideas and research papers. Your Committee publishes Research Reports from time to time in the Journal of the Sanitary Engineering Division of ASCE. Read these Reports for an evaluation of the latest research results in the field.

There are many important research problems which currently face our field of endeavor and thus your Committee. Some of the more urgent problems can be listed as:

1 - lack of adequate financial support for research

2 - low percentage of sanitary engineers actually engaged in research

3 - adopting a better means of informing our Division Members of current research in all basic disciplines of Sanitary Engineering; i.e. chemistry, bacteriology and engineering

4 - finding a procedure for bringing research needs closer to research activities

Although there was not sufficient time to discuss problem no. 4 above, the comments from panel members and the audience on the first three problems were of special importance and warrant publication in an abstracted form in this report.

1. The Federal Government is the largest contributor and benefactor of sanitary engineering research. What industry spends is quite uncertain. Last year over $800,000 was spent for water and air pollution research through the National Institutes of Health, $700,000 worth of additional research projects were approved but not carried out due to lack of funds. How many more good projects were rejected on a competitive basis? What would have happened if they had rejected Jonas Salk's research project and others just as productive in the end, but doubtful at the beginning? We must follow the example of industry and sell, sell, sell our product (research) to the people. Educators should appear in Congress to fight for more research money for sanitary engineering. Our Society should take an active part in this problem and lobby in Congress for funds. Each of us as Sanitary Engineers should talk to civic groups about the importance of research. The League of Women Voters is a powerful and well-organized national group which is deeply interested in the area of water pollution and conservation. Why not utilize their services for assistance in getting more money for research?

2. About 8 years ago the Public Health Service concluded from a survey that only about 1.9 percent of Sanitary Engineers were engaged in research. This was the lowest percentage of all engineering professions and must be even lower today. We are vitally concerned with the loss of research personnel in

the field - people like Clair Sawyer, Jess Dietz and Vernon Stack. Where are the young and vigorous researchers today to replace the greats of the past such as Dr. Rudolfs or Dr. Phelps? Even the living have deserted us - from necessity - to some degree for administration work, such as Ben Gotaas, Herman Baity, and Gordon Fair. The Federal Government should allocate funds for research as well as for construction of treatment plants - and this, in itself, would bring more researchers into the field. There is $100,000 available for traineeships under P.L. 660. However, this money has never been appropriated. Employers should give their sanitary engineers time off with pay to complete their research and thesis requirements at reputed universities. More contacts through writing and lecturing should take place with our undergraduate engineering students. The public, in general, is not being educated to the "utility of sanitary engineering." We should glamorize our Profession in the eyes of the public. Salaries of sanitary engineers should be at least as high as electrical, mechanical and other divisions in order to attract students into the field. Civil Service hiring techniques should be improved to aid in the employment situation. Several educators felt that contemporary sanitary engineering students are often the "dregs" of the engineering graduates. One reason given for this is the neglect of publicly glorifying the sanitary engineers much the same as is the case with the medical doctor and lawyer.

3. Our approach to research must stem from the basic sciences for we have almost depleted the variations of practices which exist. Our knowledge of basic science is weak; and also our lack of communication of the research in these areas is evident. How many sanitary engineers read the Journal of Bacteriology or Industrial and Engineering Chemistry? Some excuses which our engineers give are 'no time to read,' 'too much money to subscribe to all journals,' 'too little interest in basis sciences.' We have been living in a kind of smug complacency as far as our concern about basic sciences. We do not need any additional abstracts or "Digests"; all we need is to read the information that is currently available.

In summary, the panel and the audience seemed to agree that we need more MEN, MONEY, and INITIATIVE to overcome our stagnant condition in sanitary engineering. It appeared that initiative alone might be the key to and the answer to the entire situation.

Credit

This research report, which is one of a series of professional contributions by the Committee on Sanitary Engineering Research.

William T. Ingram	Air Pollution
E. R. Hendrickson	Air Pollution
Ralph Stone	Solid Wastes
R. Bogan	Sewage
C. H. Hull	Water
Milo Churchill	Stream Pollution
Harry Faber	Public Health
Chairman - Nelson L. Nemerow	Industrial Wastes.

Panel Members were Bernard Berger, USPHS, Cincinnati, Ohio; Robert Mitchell, Malcolm Pirnie Engineers; James Lamb III, American Cyanamid

Company; Martin Lang, New York City Department of Public Works; Paul Defalco, USPHS, New York City; Nelson L. Nemerow, Syracuse University; and A. F. Dappert, Water Pollution Control Board, New York State Health Department.

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

REFUSE VOLUME REDUCTION IN A SANITARY LANDFILL

Twenty-sixth Progress Report of the Committee on Sanitary Engineering Research of the Sanitary Engineering Division

ABSTRACT

An engineering investigation was undertaken to ascertain the extent of refuse colume reduction that can be achieved initially and after a long period of storage in a sanitary land fill. The resulting experimental data and field information are summarized.

INTRODUCTION

The sanitary land fill is the major method of solid waste disposal for communities in the United States. In 1946* there were less than 100 communities using this method while today there are between 1000 and 1500 communities operating sanitary land fills. The increase in urban growth has aggravated the difficulty of obtaining suitable land fill sites. Hence it is important that land fills be operated efficiently to obtain optimum volume reduction of refuse within the available valuable and limited site areas. Relatively little test data has been published concerning the physical and bio-chemical factors controlling such maximum utilization of a fill site. The Division of Highways, State of California has most generously cooperated in authorizing publication of the following information.

In November, 1957, a study was initiated to evaluate for the Division of Highways the extent and nature of the colume reduction achieved at a sanitary land fill site in Monterey Park, California. Specific phases of the investigation that were undertaken included:

Note: Discussion open until April 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2250 is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. SA 6, November, 1959.

*Private communication, Leo Weaver, Director of Research, American Public Works Association.

1. Field tests were performed to determine the volumes and type of refuse routinely disposed of during a one week observation period, December 2nd through December 8th, 1957.

2. Topographic surveys were completed to ascertain both the initial refuse land fill compaction and settlement obtained at the site during a control period of five days, December 4th through 8th, 1957, as well as that resulting after some five years of in-place settlement.

3. Special field compaction bore hole tests were used to replicate prototype land fill refuse compaction.

4. Soil tube test holes were placed within the existing land fill site at three locations so as to obtain representative core samples and temperature data for: (1) a three day old fill, (2) a two to six week old fill, and (3) a fill about one and one-half years old.

5. Land fill information was obtained from technical authorities of the California State Division of Highways, Los Angeles County Sanitation Districts, City of Burbank, Los Angeles County Engineers, Los Angeles County Flood Control District, and others.

6. A review was made of available data obtained from other land fills concerning initial in-place compaction, long period settlement, and other factors pertinent to sanitary land fill operation.

Location

The Sanitary Land Fill is located at the Davidson Site, Monterey Park, California, in the general area of McBride and Blanchard Avenues near East Los Angeles.

General History

The Sanitary Land Fill has been privately operated since 1950 with most of the fill material entering within the last five years.

Physical Factors

Topography

The Monterey Park site consists of a rolling hills area from which earth cover is excavated from both the bottom and sides of existing ravines (see Fig. 1). Three bull-dozers were used daily to perform both excavation as well as the land fill refuse compaction. A carry-all was also employed to help transport needed earth cover. Refuse was disposed of on the top of the fill and bulldozers were used to mix, compact, and push the refuse into the face of the fill approximately 20 feet deep layers (lifts). Some 2 feet of earth was then employed as cover for the compacted refuse at the end of each day's operation. After covering the fill lift, refuse vehicles and other equipment were routed over the new surface as shown in Fig. 2.

At the site, material was handled at four main zones. Solid type inert refuse, such as concrete block, brick, stone, and earth was stock piled at one zone; the majority of the refuse consisting of combustible papers, cartons, tree trimmings and other mixed combustibles was discharged from

self-unloading trucks into a second area - (see Fig. 2). Similar type refuse was also disposed into a third work area where exterior chain unloading facilities were available to aid vehicles needing such assistance - (see Fig. 3); a fourth zone was maintained to stock pile earth for eventual use as cover and admixture within the sanitary land fill.

Soil and Ground Water

Soil borings and analyses of the site soils indicated that they consisted largely of fine sandy-silt-clays. The subsurface drainage from the land fill is directly connected with the Los Angeles Central Basin ground water table, hence industrial liquid wastes were not allowed to be disposed of at the site.

Climatic Conditions

During the November-December 1957 field tests, the climatic conditions ranged from representative Southern California type dry weather to several days that were overcast, during which minor rainfall occurred.

Discussion of Sanitary Land Fill Test Operations

Public Health Considerations

Considerable trucking, car and tractor noises, odor and dust were observed at the land fill site. It was reported by Los Angeles County Fire

Fig. 1. Appearance of excavated ravine after disposal of refuse at the Monterey Park, California Sanitary Land Fill.

Department officials that it was quite common for fires to occur at the land fill and that they were normally controlled by applying additional earth cover.

Fig. 2. General view of primary Sanitary Land Fill operation at Monterey Park, California. Note the excavated slope of a former ravine into which the refuse is disposed.

Fig. 3. General view of site after land fill has been almost completed. The site is now used for secondary handling and disposal of refuse from those vehicles requiring exterior unloading help. Monterey Park, California.

Refuse Density Versus Volume

Many detailed measurements were made of refuse weight for purposes of converting volume to density. It was found that typical loosely combined refuse in an open collection vehicle averaged from 250 to 300 pounds per cubic yard. The mixed refuse in a packer type unit weighed some 425 pounds per cubic yard. Other typical data on different types of refuse, both uncompacted and inplace at a fill are described in Table I. Brush and tree trimmings showed densities averaging some 108 pounds per cubic yard with relatively little compaction occurring in the fill. Other data indicates that unless careful compaction procedures are provided, an actual expansion and thus lower density of in-place fill may result.

Refuse Volume Measurements

Between the period of November 30, 1957 and December 8th, 1957 inclusive, field data was secured to determine both the initial volumes of the refuse material as transported by truck and the compacted volumes inplace at the land fill site after being deposited and covered with earth.

Classification of refuse type and volumetric measurements were made by a field crew on all of the trucks entering the land fill. Table II summarizes the resulting information. Some three percent of all the trucks were of the compressor or self-compacting type. Altogether some ten percent of the trucks were of the completely enclosed type and an accurate determination of the material they contained was impractical. However, since they were

TABLE I

SUMMARY OF TEST DATA WITH HOMOGENEOUS REFUSE
UNCOMPACTED AND IN-PLACE FILL DENSITY

Item	No. Tests	Uncompacted Density lbs/yds^3	In-place Fill Density lbs/yds^3
Brush and tree trimmings	3	108	105
Wood (small)	3	(Sorted 499)(unsorted 127)	221
Wood (large)	3	(sorted 656)(unsorted 130)	200
Cans (tin assorted)	3	289	200
Bricks	3	sorted 3418	2484
Paper (baled)	3	251	200
Concrete (broken)	3	2835	1474
Grass	5	194	540
Paper (loose)	4	178	345
Sandy-clay soil	4	2219	2122

normally employed for conventional house to house municipal type collection, a reasonable assumption supported by truck unloading observations indicated that the refuse consisted largely of typical cellulose type materials. Records were also kept of all earth hauled to cover the dumped refuse material in compliance with land fill ordinances. The summary of the trucked refuse data as shown in Table II indicates that about eighty percent of the refuse consisted of paper, wood and garden trimmings; some six percent was inert bricks and concrete rubble; and, surprisingly, only some three percent of the earth was imported.

These data indicated that paper products derived primarily from house to house pickup were responsible for some sixty-two percent of the total volume of material handled at the land fill. Wood and lumber scraps and tree and garden trimmings respectively generated some fourteen percent and ten

TABLE II

MEASUREMENTS OF REFUSE AND SOIL COVER VOLUMES
December 2nd - 8th, 1957
Sanitary Landfill
Monterey Park, California

Date	Brick - Concrete [3]	Paper	Wood and Lumber Scraps	Tree and Garden Trimmings	Garbage and Misc. including (metal scraps)	Tires	Earth Cover	Total Loads per Day	Refuse and Cover Total Volume
	Refuse Volume Measured in Truck Yard^3								
Dec. 2[1]	472	2562	1276	698	1450	37	420	469	
3	798	6521	1669	1120	197	310	384	677	
Sub-total	1270	9083	2945	1818	1647	347	804	1146	
Dec. 4	640	7495	720	1347	122	220	504	663	
5	243	5942	939	733	108	-	59	472	
6	502	5410	1430	423	195	-	120	547	
7	183	4673	1320	719	150	-	180	516	
8	165	429	153	207	165	-	-	214	
Sub-total 4 thru 8	1733	23949	4544	3429	740	220	863	2412	35,478
Week Totals	3003	33032	7489	5247	2387	567	1667	3558	53,392
Volume % by type	5.6	61.9	14.0	9.8	4.5	1.1	3.1		

1. Start 9 AM
2. Quantity used for field survey and in-place landfill compaction control test
3. Largely construction refuse
4. Typical house to house combustible refuse

percent of the material handled. Further study of the material classification indicates that the construction industry was responsible for about fifteen percent of the total operating volume. As previously noted, some two and four tenths to three and one tenth percent of the total land fill volume consisted of earth supplied for cover or fill admixture. Table II also indicates that for the test period, the first part of the week, Monday thru Wednesday, provided the greatest quantity of refuse whereas the later portion thru Sunday generated less refuse. In all, a total of 53,392 cubic yards were handled by means of 3558 truck loads. The average truck load contained about 15 cubic yards of material, which, at an estimated 300 pounds per cubic yard is equal to 2.17 tons per average load.

On both mornings of December 4th and 9th, 1957, a survey field party completed stadia shots throughout the land fill area to determine the inplace volume achieved during this period. The fill volumes obtained from cross sections plotted from the stadia were then compared with the trucked refuse and earth cover volumes for the same period in order to determine the amount of compaction.

Topographic Survey Compaction Data

The results of these two special topographic map surveys indicate that in about one week, 27,000 cubic yards of typical sanitary land fill volume resulted from the placement of 35,478 cubic yards of original truck volume refuse and soil cover. The percentage fill volume reduction achieved is defined as that percentage representing the in-place fill volume reduction divided by the original trucked volume times 100. The percentage initial fill volume reduction for five days was about twenty-four percent, (i.e. $\frac{8,478}{35,478} \times 100\% = 24\%$).

Topographic Survey Five Year Settlement Data

Comparison of this recent aforementioned topographic data with the past topographic surveys, completed some five years before, indicated that an additional in-place fill volume reduction of about twenty-five percent had occurred. Hence, after five years for the test site, a total in-place fill volume reduction of about fifty percent resulted.

Soil Tube Investigation of Existing Fill

The purpose of the soil tube sampling survey as herein described was three-fold. First, temperature readings were obtained at an approximate depth of six feet below the surface of the fill. These readings were an indication of the rapidity of fermentation which might be expected to influence both the rate of settlement and density of the land fill. Second, a log was developed of the land fill composition within the tested areas. Third, samples were obtained for laboratory analyses to determine both moisture content and the percentage of combustibles present.

Three general areas were selected for these soil tube studies in accordance with the following land fill age criteria:

1. About three days old fill
2. Two weeks to six weeks old fill
3. One and one-half years old fill

Aerial photographs were employed to locate the older fill area placed in July, 1956. All cores were obtained with a standard type one inch diameter soil tube sampler. The steel sampler, loaded with seven (one inch diameter × six inch) brass tubes, was driven by means of a thirty-five pound hammer to a depth of six feet below the surface. The sampler was then jacked out, the soil samples were placed in a transparent bag and labeled. At the same time, approximately a fourth of the contents of each brass tube was placed in a separate bag marked "composite sample" for special laboratory testing of moisture and combustible content.

It was difficult to obtain good soil tube samples from the fill. It was found necessary for each test hole to be made by inserting the steel soil sampling tube twice - first to a depth of three and one-half feet and again to the final depth of six feet. The first insertion could recover a maximum of seven brass tubes (3.5 feet full recovery), while the second insertion only a maximum of five brass tubes (2.5 feet full recovery).

Soil tube logs were prepared for the sanitary land fill. Certain "no recovery" portions of each test hole were due to two possible causes. (1) compression of the refuse material in the tubes as the sampler was driven into the ground, and (2) the cutting head of the sampler would penetrate solid matter, such as a piece of wood or rock which would then push aside the loose fill material below it thus preventing a sample from entering the soil tubes.

After final withdrawal of the steel sampling tube, an aluminum tube was reinserted into the existing test hole. Into this tube, at the six foot level, was placed a container holding approximately one hundred cubic centimeters of water. It was found that a period of forty-five minutes provided sufficient time for the container to reach equilibrium with the fill temperature at the bottom of the hole. The container was then withdrawn and the temperature was immediately taken with a mercury thermometer. The bulb of the thermometer was then dried and the existing air temperature (in the shade) was determined and noted.

The temperatures and types of refuse encountered by the six foot depth soil tubes placed within the sanitary land fill at the three sites, each with three additional separate bore holes, are summarized as follows:

The air temperatures ranged from 52 degrees fahrenheit to 81 degrees fahrenheit and averaged 68 degrees fahrenheit. The temperatures of the six foot depth hole ranged from 85 degrees to 122 degrees fahrenheit and averaged 98 degrees fahrenheit.

All the fill samples indicated that composting action was actively taking place and that the organic refuse was being biologically reduced to gas, water soluble minerals, inerts and biological matter. It is interesting to observe that the greatest fill temperatures 86° to 122° F) were actually encountered in the one and a half year old land fill site. Moreover, all core samples indicated that much organic refuse remained for future decomposition.

The percentage moisture (dry weight) of the soil tube composite samples was 22.5 percent and contained 12.9 percent combustible material. In contrast, the various typical refuse samples, as received, contained from 17 to 34 percent moisture (dry weight) and an estimated 75 to 85 percent combustible material (dry weight).

Other Sanitary Fill Data

The percentage initial fill volume reduction* reported achieved at other sanitary land fills are described in Table III. They varied from fifty percent to seventy-five percent for various sites (except Monterey Park). Similarly, the additional settlement, following some two years of burial, measured as percentage of in-place fill volume reduction** varied from zero to

TABLE III

SUMMARY OF SANITARY LAND FILL DATA

California Cities	Initial %[6] Volume Reduction	Depth Fill per Lift (ft.)	Cover Soil Depth (ft.)	In-place Volume Reduction Measured as Settlement after Two Years[7]
Berkeley[1]	50	10	1.5	-
Burbank[2]	52	3	.75	1.5
Fresno[1]	56	15-27	4	-
Lodi[1]	73	12	2	-
Stockton[1]	52	18	2	-
Watsonville[1]	54	16	3	-
L. A. County Engineers Office[2]	50-56	-	-	-
Monterey Park[3]	23	20	1	(10-25)[5]
Other Cities				
Mandan, N.D.[2]	75	5-6	1-2	0-18
N.Y. City, N.Y.[2]	50	-	-	33
Richmond, Va.[2]	-	6-15	-	5-10
Seattle, Washington[2]	68	20	1	25
"VAM" Netherlands Composting Co.[2]	-	-	-	33
Average of 58 Cities[4]	-	4-20	-	1-25 Avg. 11

Notes:

[1]University of California Research Data

[2]Correspondence

[3]Division of Highways, State of California, Data

[4]A.P.W.A. Survey Data

[5]After five years settlement

[6]% $\frac{\text{In-place Volume} \times 100}{\text{Trucked Volume}}$

[7]% $\frac{\text{Volume Reduction} \times 100}{\text{Original In-place Volume}}$

*Percent initial of all volume reduction = $\frac{\text{in-place volume reduction} \times 100\%}{\text{initial trucked volume}}$

**Percent in-place volume reduction = $\frac{\text{volume reduction for } 2^{+} \text{ years} \times 100\%}{\text{original in-place volume}}$

thirty-three percent. The amount of such long term settlement appears to depend upon: types of refuse, soil fill characteristics, the extent of both initial depth of refuse placement and earth fill, the method of initial refuse fill compaction, moisture content, and other factors.

The in-place volume reduction that may be achieved will also depend on these initial factors as well as subsequent surface loading, subsurface fill, porosity, moisture content, climate, drainage, time period, availability of balanced nutrients for soil bacteria, the location of the ground water table, the nature of the surface use of the land fill and other factors.

Compaction and Settlement Data Discussion

Wood, concrete, brick, ashes, bundled papers, as well as other well-placed incompressible type materials would be expected to allow minimum percentage initial fill volume reduction, i.e. initial compaction. In contrast, tree trimmings, loose newspapers, paper boxes, grass cuttings, and other compressible materials may receive considerable initial compaction in a landfill site. The relatively low initial fill volume reduction achieved at the Monterey Park site (30 percent) can be attributed to the minimum tamping achieved by haphazard bulldozer and truck operations occurring over the fresh refuse in the fill, the use of large twenty foot depth lifts, minimum soil admixture, minimum water content and other factors. Considerable in-place fill settlement and percentage volume reduction would be anticipated and does occur (10 to 25 percent) at the Monterey Park site.

Experimental Compaction Test Pits

In order to simulate controlled sanitary land fill operations, a conventional type of rotary bucket drilling rig normally used to bore caisson foundations was employed to excavate thirty inch diameter test pits. Selected refuse materials in varying proportions were then placed and compacted in the test holes. Some three heterogeneous type refuse test pits and ten other homogeneous type refuse test pits were drilled to study compaction characteristics. The percentage initial fill volume reduction achieved in the three heterogeneous refuse type test holes varied from between thirty-three percent to sixty-seven percent. The detailed procedures employed were as follows:

The site of the test holes was located at the southwest corner of Blanchard and MacBride Street, Los Angeles (some five hundred feet from the land fill). This location was chosen because of proximity to the land fill and because it was available for such use.

The sandy-clay subsoil was clean, well compacted and free from rocks or other adverse materials. These factors made it possible to drill a carefully defined hole from which accurate volumes could be determined. All the test pits were drilled with the thirty inch diameter rotary bucket which weighed approximately five hundred pounds. The depth of each heterogeneous type test pit was about fifteen feet. Representative selected types of refuse were then placed in the appropriate test holes following their segregation at the dump and transportation to the site of pick-up trucks.

The loose test material was placed on a square canvas cloth and the corners folded over to form a square bundle so that the refuse could be easily

measured and weighed. The refuse material was then placed into the test pit and the depth of fill was measured from the surface ground and recorded. Normally, the drilling rig employing a combined fifteen hundred pound kelly bar plus the five hundred pound bucket was used to tamp and thus compact the refuse fill. By allowing this equipment free fall of 1.5 feet onto the refuse fill surface, each blow provided a calculated tamping force of six hundred ft lbs/ft^2. The inplace fill depth was measured from the ground surface to the top of the compacted material. These measurements described the compacted lens thickness. This procedure was normally repeated for each lift placed in the test pits.

Laboratory analyses were performed on representative refuse samples to determine pertinent refuse characteristics, (see Tables IV and V). The first compaction, Test I, replicated the operation of a land fill employing relatively thin refuse lenses compacted with admixture of soil and one foot of cover for each lens. Eleven separate lenses of refuse were placed and individually tamped into a test pit 13.6 feet deep. The representative refuse was filled to an uncompacted depth of 2.5 to 7.0 feet thickness including 0.5 feet of the clean silt-clay cover soil. The original total loose volume of 7.3 yard^3 weighing 298 lbs/yd^3 was reduced by compaction with the rig equipment to 2.47 yard^3 providing an in-place density of 891 lbs/yd^3. The percentage initial in-place volume reduction thus achieved was some sixty-seven percent, i.e. the fill density was increased about 335 percent. The materials employed in this test are shown in Table IV.

The compaction Test II replicated the operation of a land fill employing relatively thin refuse lenses compacted without soil admixture except to cover the finished fill. Six separate lenses of refuse were placed into a test hole 12.8 feet deep. Typical refuse was placed as shown in Table IV with initial fill depths of 2.8 feet to 8.2 feet thickness. Twenty blows (600 feet-pounds per square foot) were similarly applied to each lens. The typical refuse

TABLE IV

SUMMARY OF MATERIALS DATA FOR COMPACTION TEST HOLES 1 and 2

Item	Test 1* %, Loose Volume	Test 2** %, Loose Volume
Paper-cardboard	51	61
Tree Trimmings, trass	25	30
Sandy-clay cover	11	
Miscellaneous	13	9
Total	100	100
Combustibles	38	71
Non-Combustibles	62	29
Total	100	100

* With soil admixture plus soil cover for each lense

** Without soil admixture to fill, but with soil cover on last lense

contained an original loose volume of four cubic yards weighing 263 pounds per cubic yards and was reduced by compaction within the test pit to 2.63 cubic yards providing an in-place density of 399.6 pounds per cubic yards. The percentage initial in-place fill volume reduction achieved was thirty-three percent.

The third Compaction Test III consisted of replicating the operation of the Monterey Park land fill employing relatively thin refuse lenses without soil admixture except to cover the finished fill and with minimum impact compaction except for the final soil cover. Typical refuse was placed in sixteen lenses, each 1.3 feet to 7.4 feet thick. A dead weight of four hundred pounds per square foot was routinely applied to each lens depth except the final soil cover which was tampered by means of twenty blows equivalent to the standard type, 600 feet-pounds per square foot, as previously noted. The percentage initial in-place fill volume reduction achieved was about thirty percent.

Compaction Tests with Homogeneous Type Solid Wastes

Compaction tests with homogeneous type solid wastes consisted of similar type replicating operation employing relatively thin compacted refuse lenses of homogeneous material without soil admixture except to cover the finished fill. Two to four separate lenses of homogeneous refuse were placed in each separate seven foot depth test pit. Twenty blows of 600 feet-lbs/ft.^{2}, were applied to each lens. The tabulation of the original refuse density and in-place fill density is summarized in Table I.

It is interesting to observe that under the test conditions, little compaction was obtained for homogeneous mixtures of brush, wood, brick, baled paper, concrete and soil. In fact, the minimum achieved and the resulting splintering of such well assembled masses into a loose matrix actually caused "swelling" and expansion of the in-place fill volume. Fortunately, most typical refuse consisted of loose papers, boxes, cans, grass and vegetation, which were more easily compacted in a sanitary land fill.

TABLE V

LABORATORY DATA OBTAINED BY COMBUSTION OF REPRESENTATIVE REFUSE AND COVER MATERIAL

Type	% Moisture*	% Inert Material*
Cover Material (Soil)	16.9	96.6
Miscellaneous Trash (Paper products, etc.)	33.9	42.8
Garden Trimmings (Leaves, etc.)	20.1	18.7

*% by weight of the oven dry material

Other Information

It is important to differentiate between initial in-place refuse compaction and ultimate in-place refuse volume reduction and settlement achieved with the passage of time. Obviously, thin layers (2 to 4 feet) of well compacted refuse and cover soil do not settle as much as deep layers (10 to 20 feet) of refuse with a single soil cover. However, a properly designed sanitary land fill, employing thick refuse layers and little soil should provide greater settlement and thus maximum fill disposal capacity. Moisture content and other factors are important in promoting optimum compaction as well as bacterial and fungus action for composting and converting the organic refuse to gases, water, soluble and inert matter. Steel and metal refuse can also be oxidized. Competent operation of a refuse land fill should thus enable maximum volume disposal at minimum cost and nuisance.

In conclusion it should be noted that the data in Table V indicates that miscellaneous trash consisting primarily of paper products contained some 43% inert material on a day basis whereas typical garden trimmings contained about 19% inert material. The percentage moisture of the trash and garden trimmings were 34 and 20% respectively while the cover soil had 17% moisture (dry weight).

CONCLUSIONS

An investigation of refuse compaction and disposal in a sanitary land fill has resulted in the following conclusions:

1. The sanitary land fill is an economical method of solid waste disposal for American communities.

2. Relatively little test data has been published concerning physical and bio-chemical factors controlling maximum utilization of a land fill site.

3. Special topographic survey and other test data indicate that the initial in-place volume reduction achieved at the sanitary land fill under test operating conditions, was about 25% of the original trucked refuse volume.

4. Comparison of recent topographic survey over five years old indicates that an additional 25% in-place volume reduction occurred.

5. Soil tube investigations indicated that the test land fill was undergoing greater bio-logical activity following one and a half years of in-place storage than in two more youthful fills respectively one half week and six weeks old. All the fill core samples indicated that much organic refuse remained for future decomposition.

6. Other sanitary land fill sites information indicates that refuse compaction and settlement described as percentage volume reduction following two years of in-place storage ranged from 1 to 33 percent of the original in-place fill.

7. Wood, concrete, bricks, ashes, bundled papers including carefully placed inert materials generally have minimum initial fill volume compaction. In fact such homogeneous materials may actually expans as a result of fracturing and matting in a typical land fill operation.

8. Compressible organic refuse, such as loose paper, boxes, cans, grass cuttings and tree trimmings may receive maximum fill compaction in a land fill.

9. The admixture of soil to a land fill may result in improved initial refuse compaction but tends to reduce the total fill available for refuse disposal.

10. Test pits and representative select types of refuse can be employed to stimulate controlled land fill operations.

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MEAN RESIDENCE TIME OF A LIQUID IN A TRICKLING FILTER

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ABSTRACT

Pilot plant research studies aimed at broadening the basic knowledge relative to the performance of trickling filters were initiated. This paper presents the results of initial hydraulic studies in which the mean residence time was determined for tap water applied to columns packed with spherical media under conditions of varying hydraulic loading rates, media size and depth.

Background

The objective of the trickling filter research studies at the Robert A. Taft Sanitary Engineering Center is to broaden basic knowledge relative to the performance of trickling filters through analysis of experimental data secured from carefully designed and controlled experiments. It is believed that this knowledge will lead toward better designed, more effective, and more economical trickling filters.

For over half a century trickling filters have been utilized for treatment of wastes that are amenable to biochemical stabilization; consequently, the literature contains vast numbers of operational reports and theoretical discussions relative to the design, performance, and evaluation of trickling

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filters. Most of the past studies were performed on full scale filters where individual variables could not be controlled and frequently were not considered or were not susceptible to measurement. Small laboratory studies at colleges and universities, as a result of limited amounts of time, money and personnel, were generally restricted in scope to determination of the individual influence of one variable upon filter performance; however, while considerable time and effort has been expended by past workers, many questions are still unanswered and there is no commonly accepted theory of performance or method of performance evaluation based on both practical and theoretical grounds.

The Public Health Service considered a comprehensive pilot plant investigation necessary in order to study the cumulative influences of the many variables affecting the trickling filter process. The study reported herein is the initial step in this basic research program.

INTRODUCTION

It seems reasonable to theorize that the degree of purification obtained in a trickling filter is in some manner proportional to the length of time provided for biochemical change within the bed. This is by no means a new concept and much postulation and research along these lines have been done (see references 5 through 16). The initial research project was designed to determine if a correlation exists between the mean time of passage of waste liquor through a trickling filter (mean residence time) and the degree of purificiation attained.

A comprehensive trickling filter study aimed at developing design criteria should include investigation of the effect of the following variables on filter performance: hydraulic and BOD loading; amenability of feed to treatment; temperature of feed; media characteristics, including depth, size, shape, roughness, porosity, and voids; slime types and volumes of zoogloeal masses; type of distribution, distribution frequency, and recirculation. The above factors were divided into three general classifications: the physical system, the biological system, and the biophysical system. The study of the physical system is directed to the determination of the effects of the physical dimensions of the system on its hydraulic characteristics; the study of the biological system will be directed primarily to the phenomena of purification; and the research on the biophysical system will endeavor to correlate the combined effects and interaction of the physical and biological parameters. Due to the complexity of the problem, it was thought advisable to perform separate research on each of the three phases mentioned. This study, Phase I, is the initial study of the physical system dealing with the hydraulic characteristics of flow through a bed of granular media aimed at determining the mean residence time of the liquid portion of a waste (simulated by using tap water) through a clean bed of media.

Mean Residence Time

The time that a particle of fluid remains within a filter column is defined as the residence time. When a liquid is applied to the column, as in the application of sewage to a trickling filter, various portions of the liquid follow different flow patterns. With lateral and longitudinal mixing, different residence times result for different particles of fluid even though they were part of the same mass of fluid when applied to the column. The mean residence

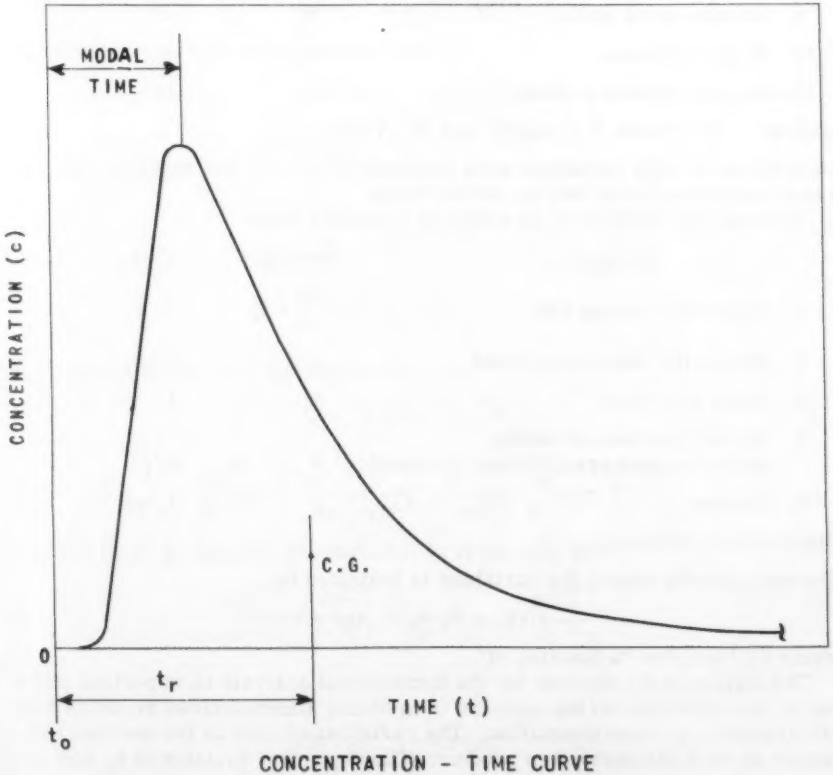
time is defined as the average residence time for all individual particles applied to the bed during a finite interval of time.

The mean residence time may be measured as follows: Let a finite quantity of tracer material be applied instantaneously at time $t_o = 0$, to the stream of fluid applied to the top of the bed. At some chosen depth, whether it be some intermediate one or at exit, the fluid is sampled and the concentration of tracer in each sample is determined. A curve of tracer concentration versus time, since the slug of tracer was applied, is plotted. Assuming that the tracer acts identically as the fluid, then the mean residence time (t_r) is, by definition, the displacement of the centroid of the area under the concentration (c) versus time (t) curve from the c axis (along the time axis) (Fig. 1). Expressing this concept mathematically

$$t_r = \frac{\int_o^\infty ctdt}{\int_o^\infty cdt} . \qquad (1)$$

The area under the curve, $\int_o^\infty cdt$, is proportional to the quantity of tracer applied. That is, $Q \times A \times \int_o^\infty cdt$ = amount* of tracer appearing in

*Weight or volume, depending upon units chosen.



CONCENTRATION - TIME CURVE

Figure 1

the effluent, where Q = hydraulic loading rate and A = area of the bed.

Experimental Design

The experimental design was based on a dimensional analysis(1) of the variables that effect the mean residence time (t_r) of a fluid in a packed bed of clean media. These variables are tabulated as follows:

Variable	Symbol	Units
1. Rate of fluid application	Q_1	L^3/T
2. Viscosity of fluid	μ	$\frac{M}{LT}$
3. Density of fluid	ρ	$\frac{M}{L^3}$
4. Surface area of bed	A	L^2
5. Depth of bed	H	L
6. Size of media	S_1	L
7. Packing density of media	S_2	-
8. Acceleration due to gravity	g	L/T^2
9. Roughness of media	R	-
10. Shape of media	S_3	-
11. Surface tension of fluid	σ	M/T^2

Where M = mass, L = length, and T = Time

Only the first eight variables were included as part of this experiment: The remaining three items will be studied later.

Refining the notation, t_r is assumed to depend upon:

Variable	Symbol	Units
1. Hydraulic loading rate	$\frac{Q_1}{A} = Q$	L/T
2. Kinematic viscosity of fluid	$\mu/\rho = \nu$	L^2/T
3. Depth of column	H	L
4. Specific surface of media, Media surface area/Volume occupied	S	$1/L$
5. Gravity	g	L/T^2

Dimensional analysis:

The relationship among the variables is indicated by

$$f_1(Q, g, \nu, H, S, t_r) = 0 \qquad (2)$$

where f ( ) denotes "a function of".

The choice of the nucleus for the dimensional analysis is important since one of the objectives of the analysis is to obtain dimensionless products that are amenable to experimentation. The variables chosen as the nucleus will appear in each dimensionless product. The dependent variable is t_r and

therefore it is desirable that it appear in only one dimensionless product. Since the factors Q, S and H can be controlled at different levels they serve as quantities useful in varying the dimensionless products making it advantageous for each to appear in only one term. The quantities g and ν were therefore selected for the nucleus in the dimensional analysis. Thus:

Nucleus	Units
g	$L/_T{}^2$
ν	$L^2/_T$

then

$$L = gT^2 \text{ and } T = L^2/\nu = \frac{g^2T^4}{\nu},$$

$$T^3 = \frac{\nu}{g^2}, \qquad T = \nu^{1/3}g^{-2/3}$$

$$\text{and} \qquad L = g^{-1/3}\nu^{2/3}.$$

Then, using the notation after Buckingham,(2)

$$\pi_1 = \frac{t_r}{\nu^{1/3}g^{-2/3}}$$

$$\pi_2 = \frac{Q}{g^{1/3}\nu^{1/3}}$$

$$\pi_3 = Sg^{-1/3}\nu^{2/3}$$

$$\pi_4 = \frac{H}{g^{-1/3}\nu^{2/3}}$$

and according to the Buckingham pi theorem

$$\pi_1 = f_2(\pi_2, \pi_3, \pi_4) \tag{3}$$

or

$$\frac{t_r g^{2/3}}{\nu^{1/3}} = f_2\left(\frac{Q}{g^{1/3}\nu^{1/3}}, \frac{S\nu^{2/3}}{g^{1/3}}, \frac{Hg^{1/3}}{\nu^{2/3}}\right). \tag{4}$$

Assuming that t is directly proportional to H we may write

$$\frac{t_r g^{2/3}}{\nu^{1/3}} = \frac{Hg^{1/3}}{\nu^{2/3}} f_3\left[\frac{Q}{g^{1/3}\nu^{1/3}}, \frac{S\nu^{2/3}}{g^{1/3}}\right] \tag{5}$$

or

$$t_r = \frac{H}{g^{1/3}\nu^{1/3}} f\left[\frac{Q}{g^{1/3}\nu^{1/3}}, \frac{S\nu^{2/3}}{g^{1/3}}\right] \tag{6}$$

For brevity, reverting to the π notation,

$$\frac{Q}{g^{1/3}\nu^{1/3}} = \pi_2 ,$$

$$\frac{t_r\, g^{1/3}\nu^{1/3}}{H} = \frac{\pi_1}{\pi_4} ,$$

$$\frac{S\nu^{2/3}}{g^{1/3}} = \pi_3 .$$

Eq. (5) becomes

$$\frac{\pi_1}{\pi_4} = f(\pi_2, \pi_3) . \qquad (7)$$

On the basis of this theoretical design, the results will plot as a family of curves displaying Eq. (7) when $\frac{\pi_1}{\pi_4}$ is plotted against π_2 for different values of π_3.

Physical Design

A. General

In order to evaluate the functional relationship set up by dimensional analysis (Eq. (7)), π_2 was varied against $\frac{\pi 1}{\pi_4}$ with π_3 constant and π_3 was varied against $\frac{\pi 1}{\pi_4}$ with π_2 constant. This was accomplished by performing a set of experiments on a column of known media size while varying the hydraulic loading rate and measuring t_r. The latter criteria may then be accomplished by performing the same experiment a number of times on beds of different size media. In essence, then, our independent variables will be Q and S and t_r the dependent one. Therefore as wide a range of Q and S as practical was desired. Also, it was necessary to keep the shape of the media constant with different sizes so that an evaluation of shape would not be necessary during this experiment. Similarly, media roughness variations were held to a minimum since this factor was neglected in the dimensional design.

B. Media

To meet the design criteria for the media, smooth spheres were chosen. They were 1/2", 3/4", and 1" diameter clean, smooth, glass spheres and 3" diameter clean, smooth, non-porous porcelain spheres. Each size packed in a different column. The choice of 3" porcelain spheres rather than glass spheres was a practical matter as the cost of 3" glass spheres was prohibitive. A different diameter column, proportional to the sphere size, was chosen for the purpose of minimizing wall effect. Table 1 presents the physical characteristics of the columns and media pertinent to the experiment.

Table 1

Media and Column Characteristics

Column:	A	B	C	D
Diameter - ft.	0.395	0.667	0.833	3.0
Height - ft.	4.1	4.1	5.9	9.0

Media:				
Type spheres	Glass	Glass	Glass	Porcelain
Diameter - in.	0.5	0.75	1.0	3.0
Total number	7,850	7,000	6,150	4,100
Surface area per sphere - $ft.^2$	0.00545	0.0123	0.0218	0.196
Volume occupied - $ft.^3$	0.503	1.43	3.22	63.5
Specific surface - $\frac{1}{ft.}$	85.0	60.3	41.6	12.6
Voids - % of volume	41	37	42	48

C. Application Rates

The choice of flow rates depended upon physical limitations and the desire to investigate flow rates in the range 1 to 200 MGAD. To facilitate metering flow over a wide range, a constant head tank was installed to supply flow to each column, the flow being varied by use of calibrated orifices. It was assumed that t_r would be a power function of Q, and therefore a geometric spacing of the rate of application was established.

D. Tracer

To ascertain the mean residence time of the passage of fluid in the column, a suitable tracer was needed. The basic criterion in the selection of the tracer was that it should exhibit the same hydraulic characteristics as the fluid.

Three tracers were considered—radioactive, organic dyes, and inorganic salts. Radiotracers were ruled out because of cost. Dyes, fluorecein and Congo Red, were investigated experimentally. It was found that the dyes adhered to the media causing significant drag-out. Sodium chloride was selected among the salts considered for use in the study when it was found that it fulfilled the criteria. Salt density currents cannot occur in the unsaturated flow conditions that prevail in this system. The concentration of chloride was low enough so that a significant change in surface tension did not take place. Between 95 and 99% of the salt added appeared in the effluent in all runs. Quantities pertaining to the tracer are presented in the tabulated results.

E. Distribution

It was necessary to minimize the effect of uneven distribution. The distribution of fluid at the inlet side of the column was therefore established by letting the flow impinge upon an inverted funnel such that the flow was distributed in a circular ring on the top of the bed. The area inscribed by the circle was one-half that of the surface area of the bed (Plate 3). The column containing the 1/2" spheres was constructed of clear Lucite so that by visual examination it was possible to observe that within three inches from the top of the bed the flow appeared uniformly distributed across the entire cross-section.

F. Sampling

Each sample was obtained by collecting the total flow issuing from the column over an increment of time sufficient to collect 50 to 200 ml. for analysis. Since the sample constituted the total flow passing the exit cross-section for a finite time, it represented an average across the entire cross-section, thus minimizing the possible effect of uneven channeling.

Operating Procedure

The column was first flushed with water, and a specific, continuous flow rate of tap water was applied. Two hours were allowed for establishment of flow equilibrium. The tracer was added, at time $t_o = 0$, to the inlet stream of water above the surface of the bed in such a manner that it would thoroughly mix with the water. Analysis of data secured during trial runs indicated that the apparent mean residence time varied slightly with varying quantities of tracer, all other conditions being equal. This was due to the increased measurability of the tail of the flow-through curve when large quantities of tracer are used. It was decided, therefore, to keep the quantity of tracer applied in constant proportion to the quantity of flow in order to minimize the relative effect. The quantity of tracer added in a run was taken as 0.4 mg. of N_aCl per ml./min. of flow. The tracer was a 6% solution. The trial runs also indicated the best frequency of sampling, dependent upon the bed and flow rate. At least three samples were obtained for the ascending portion of the flow-through curve (Fig. 1) and from two to four samples to describe the peak (mode). The remaining samples were taken to describe the tail of the curve. The usual volume of sample was from 50 to 200 ml. The chloride content of the sample was determined by the Mercuric Nitrate Method[3] and t_r was evaluated as described.

Results

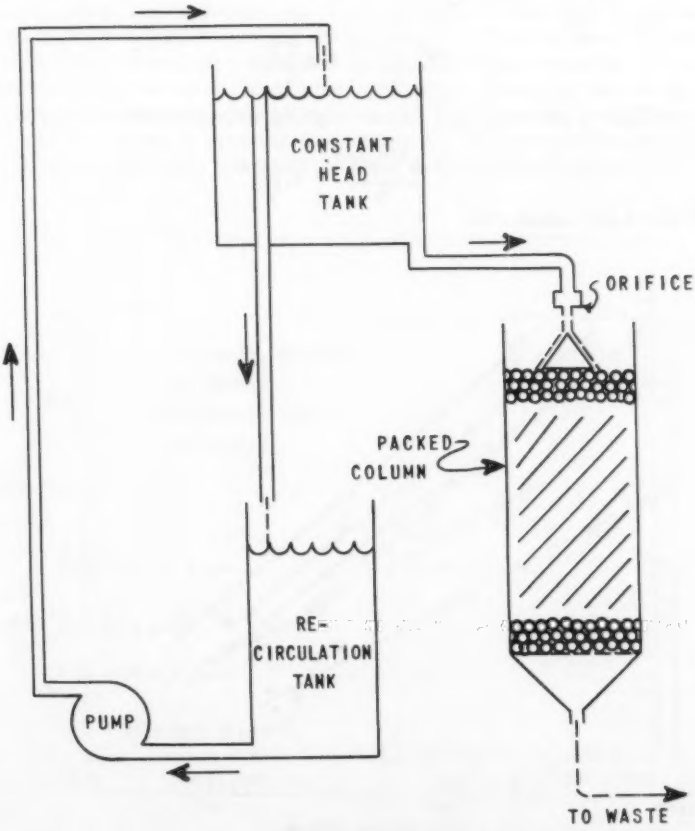
Tables 2 through 5 present the measured and computed data secured from the four columns during the experiment. The measured flow rates are given in million gallons per acre per day (MGAD) and in cubic feet per square foot per second (ft./sec.). The effluent temperature and corresponding kinematic viscosity are listed for each run, as are the quantity of tracer used, the

Fig. 2 is a schematic representation of the flow system.
Plates 1 - 6 are photographs of the system.

computed mean residence times in seconds and the corresponding dimensionless products (π_1/π_4), π_2 and π_3. The dimensionless products are displayed in graphical form in Fig. 3.

Analysis of Data

Examination of the dimensionless plot (Fig. 3) indicates a family of curves as suggested in the theoretical experiment design. Analysis of these curves, however, showed that the curves could be re-arranged into a more descriptive function by dividing the quantity π_2 by the quantity π_3 and plotting this new parameter $Q/S\nu$ vs. the time function (π_1/π_4). The quantity $Q/S\nu$ is a form of Reynolds' number, or more correctly, a modified Reynolds' number. Fig. 4 is a plot of the data based on this transformation. It shows that the curves have now been collapsed, the three curves representing the glass spheres into one curve, and the curve representing the porcelain spheres into another. It



SCHEMATIC DIAGRAM OF FLOW SYSTEM

Figure 2

becomes apparent from this plot that we are dealing with two distinct physical traits. The three columns packed with glass spheres display different time characteristics than the column packed with porcelain spheres. Whether the difference in the two systems is caused by a sudden transition in physical action at low specific surface or by the different wetting and roughness characteristics of the media cannot be determined without further research. We suspect the latter is true and feel that an evaluation of roughness characteristics must be made before these data may be used in practical applications.

Theoretical Equation

Fig. 4 facilitates the graphical evaluation of the constants for a theoretical equation for t_r. Referring to the dimensional analysis and to the above transformation, the form of this equation is

$$\frac{\pi_1}{\pi_4} = f\left(\frac{\pi_3}{\pi_2}\right) \tag{8}$$

or

$$\frac{t_r g^{1/3} \nu^{1/3}}{H} = f\left(\frac{S\nu}{Q}\right).$$

Since Eq. (8) plots as a straight line on log-log coordinates, we may write

$$\frac{t_r g^{1/3} \nu^{1/3}}{H} = K\left(\frac{S\nu}{Q}\right)^n \tag{9}$$

where K and n are constants.

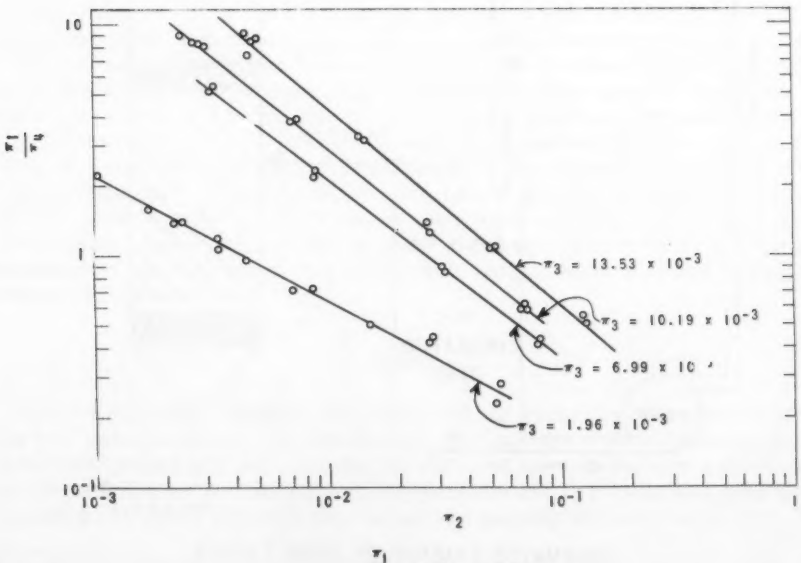


Figure 3

For the glass spheres K = 3.0 and n = 0.83 and for the porcelain spheres K = 1.5 and n = 0.53. Thus, for glass spheres

$$t_r = 3.0\,\frac{H\nu^{1/2}}{g^{1/3}}\left(\frac{S}{Q}\right)^{0.83} \tag{10}$$

and for porcelain spheres

$$t_r = 1.5\,\frac{H(\nu)^{0.20}}{g^{1/3}}\left(\frac{S}{Q}\right)^{0.53} . \tag{11}$$

Discussion

A. Experimental Results—Use of Theoretical Equations

Eqs. (10) and (11) may be used to predict values of mean residence time for systems similar to the one on which this experiment was conducted. As an example of the possible future use of an equation of this type, suppose it is determined in future studies that the efficiency of a trickling filter is some function of the mean residence time and that one could compute the required mean residence time to yield the desired efficiency. Then, by use of Eq. (10) or its counterpart for a biophysical system, the loading rate, specific surface and depth may be varied to give the most economical combination providing the desired mean residence time and thus the desired purification.

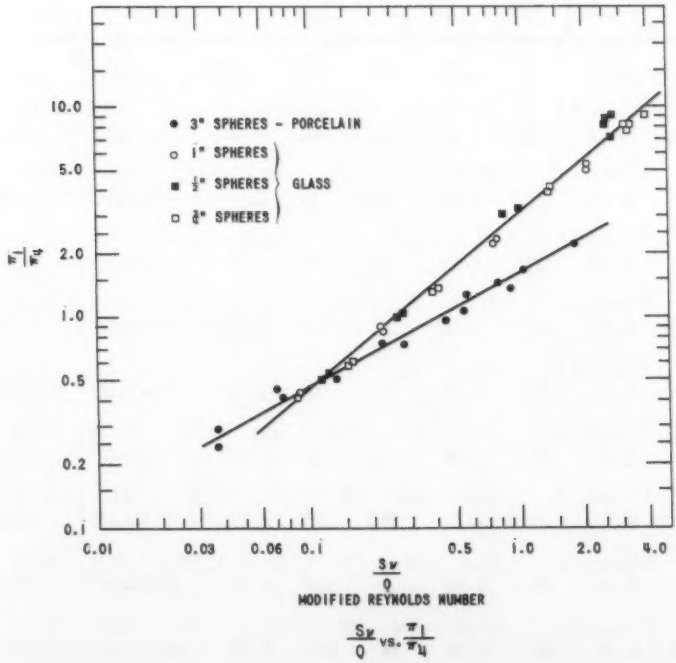


Figure 4

B. Analysis of the c vs. t Curve for Mean Residence Time

Three methods of analysis (determination of centroid) of the concentration (c) versus time (t) curve for t_r were investigated. They were: 1) mathematical method; 2) graphical integral evaluation method; and 3) model method.

1. The Mathematical Method

The mathematical method requires finding the function relating c to t. Using this relationship Eq. (1) may be integrated and t_r solved for directly. For the curves obtained, the ascending portion of the curve closely approximated a logistic function and the descending portion closely approximated a double exponential-type function. The effluent from the column during the descending portion of the curve may be considered in 2 phases. Phase I represents the tracer (or fluid) that constitutes that portion of the total fluid in the column which one considers flowing through. The literature terms this fluid the "operating holdup." Some of the fluid, due to boundary layer theory and the velocity profile in general, does not flow through at the same rate as the

Table 2

Tabulated Results
Column A

Run	Hydraulic Loading Rate		Effluent		NaCl	t_r	Dimensionless Products		
			Temp.	ν			π_1/π_4	π_2	π_3
	MGAD	ft/sec x 10^3	°C	ft^2/sec x 10^5	Mg	Sec	-	-	- x 10^2
1	28.8	1.02	15	1.23	90	183	3.28	1.39×10^{-2}	1.43
2	8.87	0.32	22	1.02	31	440	7.40	0.45×10^{-2}	1.26
3	269	9.55	10	1.41	770	29	0.55	1.24×10^{-1}	1.56
4	106	3.76	17	1.17	320	61	1.07	5.21×10^{-2}	1.38
5	9.28	0.33	22	1.02	29	516	8.69	4.78×10^{-3}	1.26
6	28.4	1.01	23	1.00	90	189	3.15	1.47×10^{-2}	1.22
7	105	3.73	14	1.26	336	60	1.08	5.03×10^{-2}	1.45
8	276	9.79	13	1.30	780	28	0.51	1.31×10^{-1}	1.48
9	8.54	0.30	24	0.99	39	558	9.31	4.43×10^{-3}	1.23
10	9.42	0.34	22	1.02	34	492	8.28	4.86×10^{-3}	1.26

"operating holdup." This portion of the flow comes off at a much slower rate and is termed Phase II. Since the concentration of tracer in the effluent should be proportional to the amount remaining in the column, we may write:

$$\frac{dc_1}{dt} = a_1 c_1 . \tag{12}$$

Solving the differential equation:

$$c_1 = b_1 e^{a_1 t} \tag{13}$$

where c_1 is concentration due to Phase I.
Similarly for Phase II

$$\frac{dc_2}{dt_2} = a_2 c_2 \tag{14}$$

Table 3

Tabulated Results
Column B

Run	Hydraulic Loading Rate		Effluent Temp.	Effluent ν	N_aCl	t_r	Dimensionless Products π_1/π_4	π_2	π_3
	MGAD	ft/sec x 10^3	°C	ft^2/sec x 10^5	Mg	Sec	-	-	-
1	144	5.14	12	1.34	1200	32	0.59	6.80×10^{-2}	1.07
2	144	5.14	12	1.34	1200	32	0.59	6.80×10^{-2}	1.07
3	4.86	0.17	13	1.14	42	517	9.03	2.42×10^{-3}	0.96
4	14.5	0.52	17	1.19	120	215	3.80	7.16×10^{-3}	0.99
5	58.3	2.08	10	1.41	480	74	1.39	2.70×10^{-2}	1.11
6	151	5.37	10	1.41	1200	33	0.61	6.97×10^{-2}	1.11
7	59.2	2.11	12	1.36	480	68	1.26	2.78×10^{-2}	1.09
8	5.44	0.19	20	1.08	60	480	8.23	2.76×10^{-3}	0.92
9	5.50	0.20	20	1.08	54	480	8.23	2.79×10^{-3}	0.92
10	5.50	0.20	20	1.08	52	474	8.13	2.79×10^{-3}	0.92
11	15.6	0.56	14	1.29	150	214	3.88	7.47×10^{-3}	1.04

and

$$c_2 = b_2 e^{a_2 t} \tag{15}$$

then

$$c = c_1 + c_2 = b_1 e^{a_1 t} + b_2 e^{a_2 t} . \tag{16}$$

Referring to Eq. (1) and assuming a logistic for the ascending portion of the curve,

$$t_r = \frac{\int_{t_1}^{t_2} \frac{t c_{t_2}}{1 + x e^{rt}}\, dt + \int_{t_2}^{\infty} (b_1 t e^{a_1 t} + b_2 t e^{a_2 t})\, dt}{\int_{t_1}^{t_2} \left(\frac{c_{t_2}}{1 + x e^{rt}}\right) dt + \int_{t_2}^{\infty} (b_1 e^{a_1 t} + b_2 e^{a_2 t})\, dt} \tag{17}$$

where t_1 = time of initial trace

t_2 = modal time

r & x are the logistic parameters

ct_2 = concentration at mode.

Table 4

Tabulated Results
Column C

Run	Hydraulic Loading Rate		Effluent Temp.	Effluent ν	N_aCl	t_r	Dimensionless Products π_1/π_4	π_2	π_3
	MGAD	ft/sec x 10^3	^oC	ft^2/sec x 10^7	Mg	Sec	-	- x 10^2	- x 10^3
1	169	6.01	13	1.30	2400	35	0.44	8.04	7.24
2	66.2	2.35	14	1.28	780	70	0.89	3.16	7.16
3	66.2	2.35	14	1.26	780	69	0.87	3.18	7.11
4	18.5	0.66	15	1.23	264	180	2.24	0.90	6.99
5	169	6.01	13	1.30	1500	33	0.42	8.04	7.24
6	184	0.65	15	1.23	245	182	2.27	0.89	6.99
7	6.16	0.22	18	1.14	102	420	5.09	0.31	6.61
8	6.31	0.22	18	1.14	120	438	5.31	0.31	6.61

Table 5

Tabulated Results
Column D

Run	Hydraulic Loading Rate		Effluent		N_aCl	t_r	Dimensionless Products		
			Temp.	ν			π_1/π_4	π_2	π_3
	MGAD	ft/sec	°C	$ft^2/sec \times 10^5$	Mg	Sec	-	- x 10^2	- x 10^3
1	4.36	1.55×10^{-4}	19	1.13	720	175	1.38	0.22	1.99
2	17.3	6.16×10^{-4}	20	1.08	3000	94	0.74	0.88	1.93
3	107	3.82×10^{-3}	18	1.14	18000	30	0.24	5.34	2.00
4	55.9	1.99×10^{-3}	17	1.17	9110	52	0.42	2.76	2.04
5	57.4	2.04×10^{-3}	17	1.17	9000	55	0.44	2.83	2.04
6	2.06	7.31×10^{-5}	20	1.08	600	279	2.18	0.10	1.93
7	6.81	2.42×10^{-4}	19	1.11	1200	158	1.24	0.34	1.97
8	29.4	1.05×10^{-3}	19	1.11	6000	65	0.51	1.47	1.97
9	14.0	5.00×10^{-4}	19	1.11	3000	90	0.71	0.71	1.97
10	109	3.87×10^{-3}	18	1.14	15000	36	0.287	5.41	2.00
11	9.01	3.21×10^{-4}	18	1.14	1800	120	0.95	0.45	2.00
12	6.63	2.38×10^{-4}	22	1.02	900	140	1.07	0.34	1.86
13	4.62	1.65×10^{-4}	21	1.05	900	183	1.42	0.24	1.90
14	3.39	1.21×10^{-4}	21	1.05	600	210	1.62	0.17	1.90

When integrated, Eq. (7) becomes approximately,

$$t_r = \frac{\frac{c_{t_2}}{6}(2t_2^2 - t_1t_2 - t_1^2) - \frac{b_1e^{a_1t_2}}{a_1^2}(c_1t_2 - 1) - \frac{b_2e^{a_2t_2}}{a_2^2}(c_2t_2 - 1)}{c_{t_2}\frac{(t_2-t_1)}{2} - \frac{b_1e^{a_1t_2}}{a_1} - \frac{b_2e^{a_2t_2}}{a_2}} \quad (18)$$

In the analytical determination, the constants in Eq. (18) may be evaluated by graphical means and may then be solved for t_r.

2. Graphical Integral Evaluation Method

In order to evaluate t_r graphically we may plot t versus c and measure the area under the curve. When this method was used in this experiment, the area was determined both by planimeter and Simpson's rule. As previously mentioned this quantity is $\int c\,dt$. (The value of the upper limit being of practical consideration as discussed later.) The quantity $\int ct\,dt$ may be evaluated as the area under the ct versus t curve. That is, plot concentration times time versus time and obtain its area. t_r is obtained by dividing the latter area by the former.

3. Model Method

The procedure was to plot concentration versus time on a piece of cardboard and the resulting shape was cut out. The form was then balanced on a knife edge so that the line of contact between the knife edge and the cardboard would be the axis, perpendicular to the abscissa (t axis), passing through the centroid.

Comparison of the Three Methods

The first 15 curves obtained using sodium chloride were used for a comparison of the three methods. For any given curve the variation in t_r from one method to another was always less than 5 per cent, with no trend as to one method giving consistently greater or lesser values. The model method was the most convenient and thus was the one chosen for routine use.

C. The "Tail" of the Curve

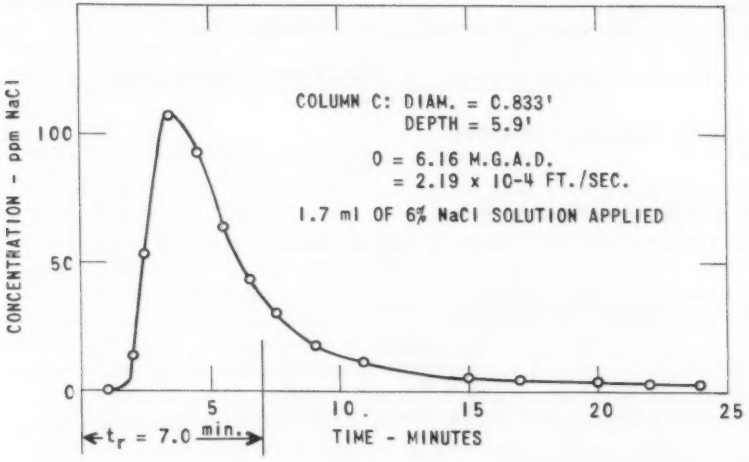
As is the case with flow-through measurements of this nature, the skewness of the curve is such that there is a pronounced tail which is very influential on a second moment measurement. (See Fig. 5) Theoretically, the mean resistance time would be infinite if only one minute particle of tracer remain within the bed for an infinite time. To add to the difficulty, the measurements of tracer along the tail are obviously less accurate percentagewise than measurements near the mode. The method used in computing t_r (by the model method) aided in alleviating the difficulty. When the analytical error in measurement of tracer exceeded 25% of the concentration, measurement was discontinued and a smooth curve extrapolated to give a reasonable die-off. This technique worked quite well since replicate runs gave results that were in close agreement as indicated in the tabulated results.

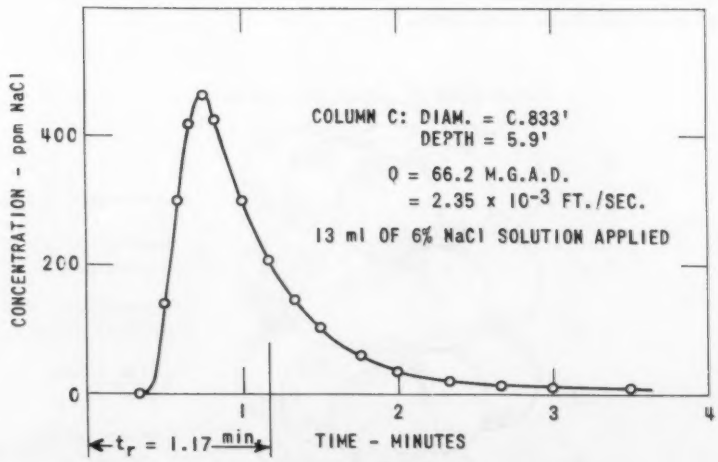
The influence of the tail of the curve on the time measurement could be minimized by using another criterion for time such as the modal time or the median time. It was assumed, however, that for later correlation with

D. The Media

Specific Surface and Sphere Packing

In the computation of specific surface it is necessary to include the effect of void space. One may mistakenly compute the specific surface of any sphere packing as





ACTUAL FLOW-THROUGH CURVES

Figure 5

$$\frac{\text{Surface area of one sphere}}{\text{Volume occupied by the sphere}} = \frac{\pi d^2}{\frac{\pi d^3}{6}} = \frac{6}{d} \tag{19}$$

where d = diameter of spheres.

The only arrangement of spheres that Eq. (19) is applicable to is a rectangular arrangement shown in Fig. 6. Because of the many possible packing arrangements, the specific surface must be computed as

$$S = \frac{\text{Number of spheres x surface area of one sphere}}{\text{Volume occupied}} . \tag{20}$$

Then, if the void space is known

$$S = N\pi d^2 \tag{21}$$

where N = Sphere/cu. foot. But

$$N = \frac{(1 - V)6}{\pi d^3} \tag{22}$$

where V = fraction of voids. Therefore

$$S = \frac{(1 - V)6\pi d^2}{\pi d^3} = \frac{6(1 - V)}{d} . \tag{23}$$

Table 1 shows column and media characteristics.

E. Wall Effect and Scale-Up

Because of the possibility of "wall effect" (part of the flow short-circuiting down the walls of the column and thereby interfering with the usual flow process) it would be desirable to keep the ratio of the specific surface of the walls of the column to the specific surface of the media as small as practical and constant from column to column. Keeping the ratio constant from column to column in no way eliminates "wall effect" but should, however, provide the same degree of influence in all beds.

RECTANGULAR PACKING

Figure 6

"Wall effect" should tend to decrease the apparent mean time, since the flow down a straight vertical wall is less tortuous than around, and over the media. We might expect, therefore, that the results of this experiment tend to give values of t_r that are smaller than if there was no "wall effect."

Previous work(4) indicates, however, that if the ratio of tower to packing diameter is equal to or exceeds eight to one, "wall effect" becomes negligible and scale-up difficulties are minimized. Since the ratio of column diameter to media diameter herein exceeded eight to one in all cases (Table 6) we would expect the error in the value of t_r due to "wall effect" to be small and thus making these data useful in prediction of t_r when applied to a large-scale setup.

Theoretical Derivation Based on Physical Laws

Howland(5) derived an equation for the time of flow over a single sphere assuming the liquid was applied at the very top, spread out over the entire sphere, and left at the very bottom. Actually, as Dr. Howland recognizes, and as we have confirmed by visual examination, these assumptions are open to questions. Unless a wetting agent is added, the liquid tends to channel instead of spreading over the sphere. Where the liquid starts on a sphere and where it leaves is a function of the places of contact with adjacent spheres. Because it is believed that these assumptions distract from the true physical situation no correlation will be drawn between the theoretically assumed and actual, as they are distinctly two different cases. It should be pointed out, however, that if a slime is developed on the entire sphere the fluid will spread over the entire sphere and the error due to that assumption is minimized. The effect of slime itself, however, introduces quite a different factor for consideration, and will be evaluated in future experiments. Howland's equation is as follows:

$$T_s = 2.6 \left(\frac{3\nu}{g}\right)^{1/3} (2\pi)^{2/3} \frac{r^{5/3}}{(Q')^{2/3}} \qquad (24)$$

Table 6

Ratios Pertinent to Wall Effect

	A	B	C	D
Column diameter ft.	0.395	0.667	0.833	3.00
Specific Surface of column wall $ft.^2/ft.^3$	10.1	6.0	4.8	1.33
Specific Surface of media $ft.^2/ft.^3$	85.0	60.3	41.6	12.6
Per cent $\frac{S\ Wall}{S\ Media}$	11.9	9.9	11.5	10.5
$\frac{Diameter\ column}{Diameter\ media}$	9.5:1	10.7:1	10.0:1	12.0:1

T_s = Time of flow around one sphere from top to bottom.

r = Radius of sphere.

Q' = Total flow on one sphere.

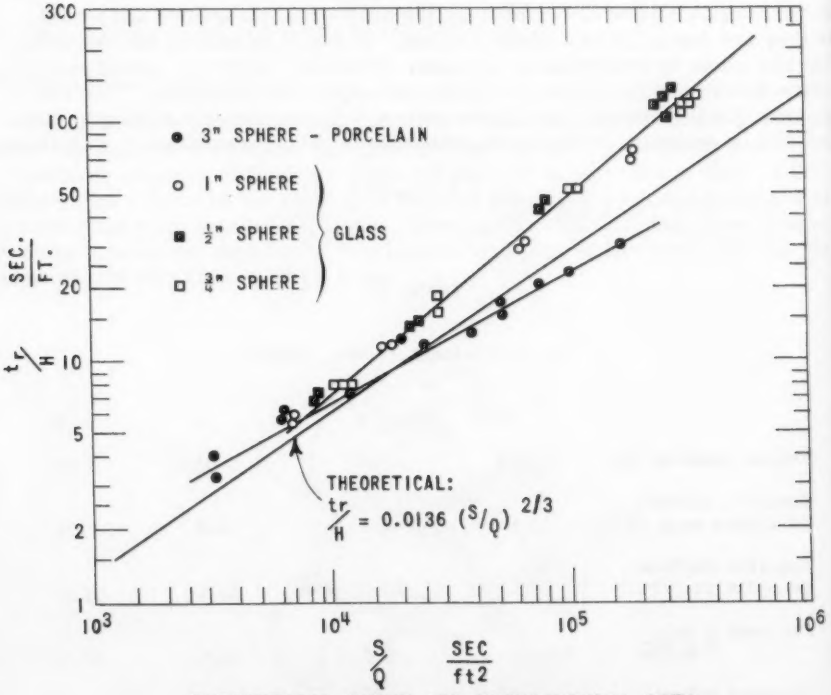
Transforming this equation into the notation used in this paper (see Appendix) we obtain

$$T_r = 1.3\ H\left(\frac{3\nu}{g}\right)^{1/3}\left(\frac{S}{Q}\right)^{2/3}. \tag{25}$$

Assuming a fluid temperature of 15° C and evaluating the known quantities, Eq. (25) becomes

$$\frac{T_r}{H} = 0.0136\left(\frac{S}{Q}\right)^{2/3}. \tag{26}$$

Fig. 7 is a plot of Eq. (26) with the experimental data indicated for comparison. Referring to Fig. 7, we are again aware of two distinct regimes. The set of data from the three columns containing the glass spheres gives different results from that set of data of the porcelain spheres. The difference may be attributed to many factors, and, to reiterate, they include



THEORETICAL CURVE AND EXPERIMENTAL DATA

Figure 7

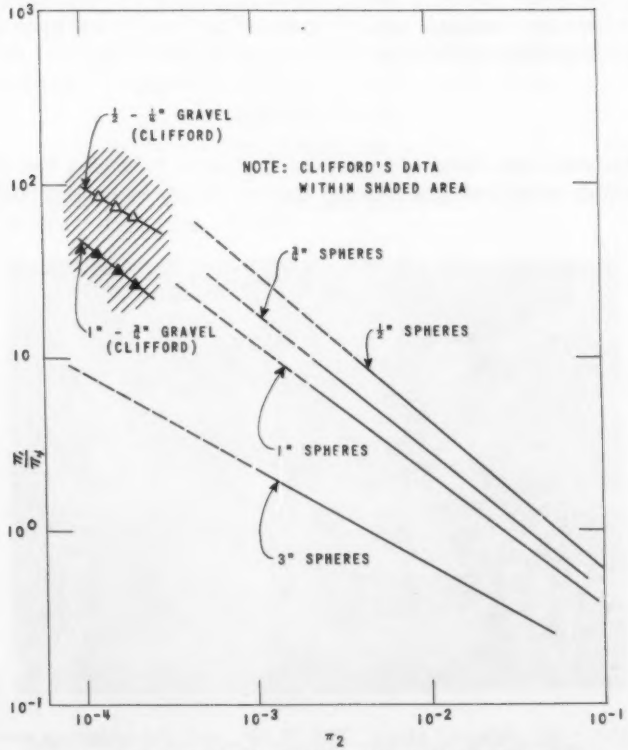
1. Different wetting effect between glass and porcelain.
2. Different roughness characteristic between glass and porcelain.

Again, the important conclusion concerning the above facts is that, with two different physical systems we obtained two different sets of results, with the same physical system we obtained the same set of results based on theoretical parameters. We must, then, be aware of this fact when applying these data to different physical systems.

Past Time Studies and Relationship to Chemical Industrial Processes

Various attempts to measure the time of flow through a trickling filter have been made.(6,7,8,9,10,11,12,13,14,16,16)

The only full scale attempt using clean media seems to have been done by Clifford(7) in 1907. Through uncertainties as to periodicity of dosing the specific surface of his media and the porosity of his media we are prevented from drawing any definitive correlation between his data and the experimental data presented herein. Nevertheless, referring to Fig. 8, observe that, in light of his data, the experimental curves may be extrapolated into the lower loading ranges without resulting in an appreciable error.



COMPARISON OF EXPERIMENTAL DATA WITH THAT OF CLIFFORD

Figure 8

The results of the other experiments are applicable, in general, only to the particular filter on which the experiment was run. No general equations or formulations, as of the type developed here, seem to have evolved.

A review of the literature reveals that flow through granular media has application in many fields. The literature of the chemical industry dealing with flow through packed towers is extremely extensive.[4,17,18,19,20] Little imagination is required in recognizing the similarity between a trickling filter and a packed tower. Besides the fact that the usual flow rates in the chemical industry's packed towers are in the order of 10 to 100 times as great as in a trickling filter, the most striking dissimilarity is in the media used, although the processes involved are similar. Chemical industry uses such efficient shapes as berl saddles and rashig rings to provide high specific surfaces, whereas rock with a relatively low specific surface has been the mainstay in sewage treatment. Whether rock is an inefficient shape remains to be determined. If by future experimentation it is shown that filter efficiency is directly proportional to mean residence time, and therefore a higher specific surface would be desirable (Eqs. (10) and (11)), then rock may be considered relatively inefficient. For example, the commonly used 3" rock (specific surface = 15 ft.$^{-1}$) would yield a mean residence time of only about 1/4 of that of 1" berl saddles (S = 76 ft.$^{-1}$), all other things being equal. It is thought that important research on trickling filters may be in the area of comparison of trickling filters with packed towers. The tremendous store of knowledge available within the chemical industry pertaining to packed towers would be available to the development of a new approach to trickling filter design.

CONCLUSIONS

The mean residence time of a clean fluid flowing through a bed of clean, loosely packed, unsaturated nonporous media, within the ranges stated herein is:

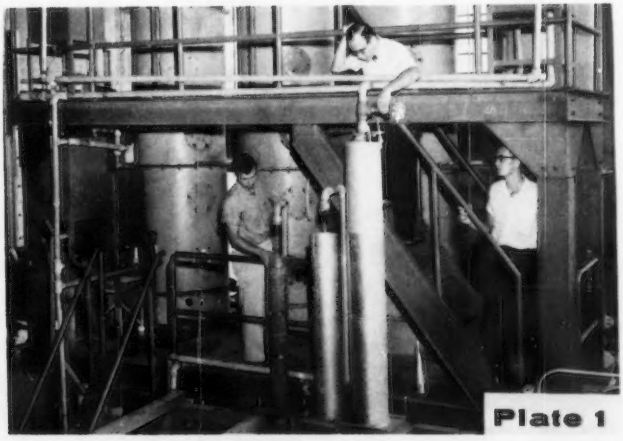


Plate 1. Over-all physical plant. The 5", 8", and 10" columns are in the foreground. The 3' diameter columns are in the background.

1. Inversely proportional to the 0.83 power of the hydraulic loading rate for glass spheres and to the 0.53 power for the porcelain spheres.
2. Directly proportional, to the same powers, to the specific surface.
3. Directly proportional to the 0.5 power of the kinematic viscosity for the glass spheres and to the 0.20 power for the porcelain spheres.

Further research is needed in investigating the effect of the following on t_r:

1. Surface tension of fluid.
2. Shape of media.
3. Roughness of media.
4. Biological entities (slime, solids, etc.)

Research is desirable in correlating the trickling filter process to flow through a packed tower.

SUMMARY

A relationship between mean residence time and 1) hydraulic loading rates; 2) specific surface; 3) kinematic viscosity; 4) gravity; and 5) depth of bed, was obtained for flow over clean spherical media. The approach was in the form of a dimensional analysis and experimentation on the independent dimensionless products to find their effect on the dependent dimensionless product. An empirical equation is developed from these data and the possible application of this equation as it applies to future research is presented.

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Plate 2. Top of the 3' diameter column with distribution device removed. This column packed with 3" diameter porcelain spheres.

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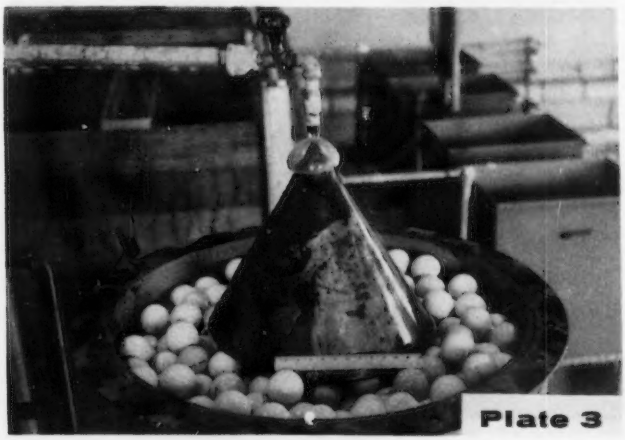

Plate 3. Top of the 3' column showing distribution device.

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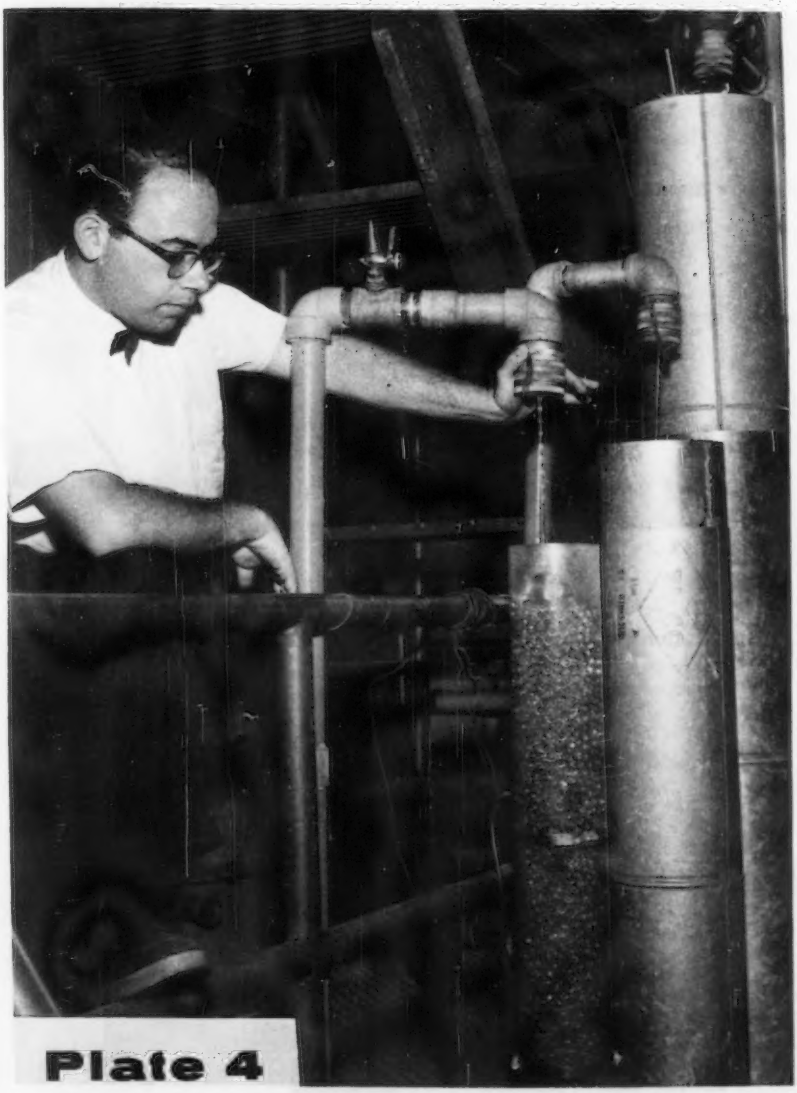

Plate 4. The 5", 8", and 10" columns and orifice distribution.

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APPENDIX

$$T = 2.6 \left(\frac{3\nu}{g}\right)^{1/3} (2\pi)^{2/3} \frac{r^{5/3}}{Q'^{2/3}} \qquad \text{(Howland's Equation)} \qquad (24)$$

Let N_h = Number of spheres per square foot of horizontal section.*

N = Number of spheres per cubic foot,

$$N = N_h \times \frac{1}{2r}.$$

Specific surface = $N \times 4\pi r^2 = S$,

$$N = \frac{S}{4\pi r^2},$$

then

$$\frac{S}{4\pi r^2} = \frac{N_h}{2r}, \quad N_h = \frac{S}{2\pi r}. \qquad (27)$$

Q' = Total flow on one sphere,

Q = Total flow per square foot of column cross section,

$$Q = Q' \times N_h, \quad Q' = \frac{Q}{N_h} = \frac{2\pi r Q}{S}. \qquad (28)$$

*All computations are based on an assumed rectangular packing.

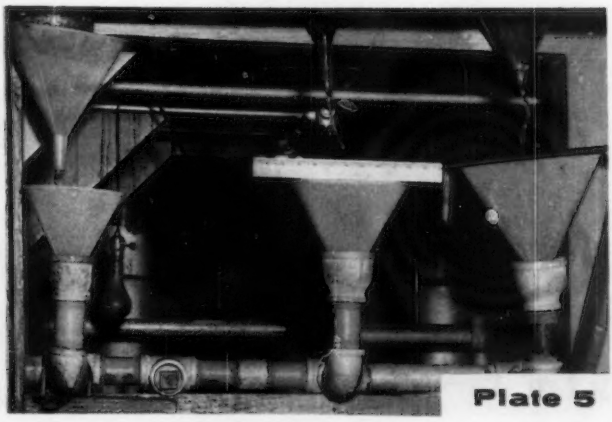

Plate 5. Exits from 5", 8", and 10" columns with collection funnels in place.

$$T_S = 2.6 \left(\frac{3\nu}{g}\right)^{1/3} (2\pi)^{2/3} \times \frac{r^{5/3}}{(2\pi)^{2/3}} \frac{S^{2/3}}{(r)^{2/3} Q^{2/3}}, \quad (29)$$

$$T_S = 2.6 \left(\frac{3\nu}{g}\right)^{1/3} \frac{rS^{2/3}}{Q^{2/3}}. \quad (30)$$

T_S = Time for one sphere.

N_v = Number of spheres in vertical direction.

$$T_S N_v = T_r,$$

H = Depth of packing (column)

$$N_v = \frac{H}{2r},$$

$$T_S \frac{H}{2r} = T_r.$$

Then

$$T_r = 2.6\ H \left(\frac{3\nu}{g}\right)^{1/3} \times 1/2 \times \left(\frac{S}{Q}\right)^{2/3},$$

$$T_r = 1.3\ H \left(\frac{3\nu}{g}\right)^{1/3} \left(\frac{S}{Q}\right)^{2/3}. \quad (31)$$

Assume temperature = 15° C

$$\nu = 1.23 \times 10^{-5}\ \text{ft.}^2/\text{sec.}$$

$$\frac{T_r}{H} = 1.3 \frac{(3 \times 1.23 \times 10^{-5})^{1/3}}{32.2} \left(\frac{S}{Q}\right)^{2/3},$$

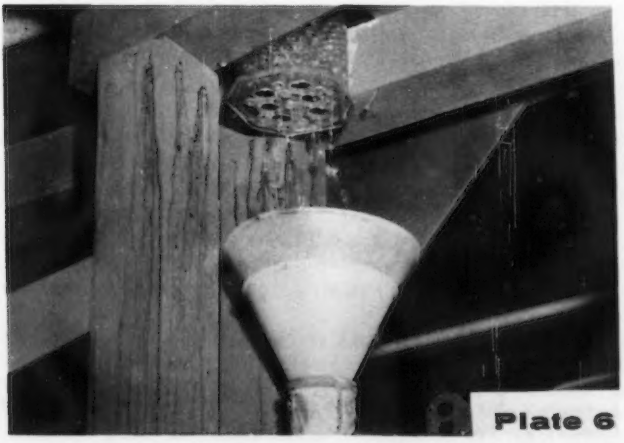

Plate 6. Exit from 5" column showing collection funnel removed.

$$\frac{T_r}{H} = 1.3\ (1.147 \times 10^{-6})^{1/3}\ \left(\frac{S}{Q}\right)^{2/3},$$

$$\frac{T_r}{H} = 1.3\ (1.0466)\ (10^{-2})\ \left(\frac{S}{Q}\right)^{2/3},$$

$$\frac{T_r}{H} = 0.0136\ \left(\frac{S}{Q}\right)^{2/3}. \qquad (26)$$

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WASTE WATER RECLAMATION FOR GOLF COURSE IRRIGATION[a]

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ABSTRACT

The Sanitary Engineering Research Laboratory of the University of Southern California, Los Angeles, has completed a three year study of waste water reclamation and utilization. While the investigation embraced the feasibility of reusing waste waters for recreational, agricultural, and industrial purposes, as well as ground water recharge, it was the first of these which appeared to hold early promise. This paper, then, discusses the general considerations for reuse of reclaimed waste water for golf course irrigation, and cites a number of installations where successful use of reclaimed waters is being accomplished.

The study was sponsored by the California State Water Pollution Control Board.

Since World War II, there has been an increased use for waste water in the maintenance of golf courses. In California, Nevada, Texas, Arizona, and New Mexico, installations for use of waste waters for this and other recreational purposes have occurred. New installations for use of waste water for golf courses are proposed in California. The future application of reclaimed sewage for irrigation of golf courses appears to hold considerable promise. Before presenting facts, figures, and case histories of some of the successful golf course developments predicated on the irrigational use of reclaimed sewage, some of the more general considerations should be discussed.

Sanitary engineering practices make it possible to produce a dependable effluent suitable for golf course use with a minimum of public health hazard and aesthetic problems. This has been demonstrated at various locations throughout the southwestern part of the United States. In addition to

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a. Presented at the February 1959 ASCE Convention in Los Angeles, Calif.

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reclaiming waste waters for the purpose of providing a source of recreation for the general population, there is a reduction in the amount of sewage which otherwise might require other treatment. There is also a conservation of available potable water for other higher uses. The net result will be the increasing of the total available water supply without providing the facilities for developing other supplies. It should also be pointed out that the re-use of waste waters eliminates the necessity for discharge of sewage to restricted bodies of water where their pollution would be detrimental to other uses.

The mineral and organic quality requirements of a waste water are not as critical for recreational irrigation as for general agricultural irrigation. Most grasses, bushes and trees are not as sensitive to high percentage sodium and total dissolved solids as are many agricultural crops.

The beneficial fertilizer elements present in reclaimed effluent are an important consideration in golf course irrigation. Effluents may contain 40 to 60 ppm available total nitrogen, 5 to 50 ppm phosphate as P_2O_5, and approximately 10 to 60 ppm potash as K_2O. The value of humus as a soil conditioner may be of even more importance than the fertilizing elements. Golf course operators consistently report that waste water is superior to alternate potable waters for the growth and maintenance of the vegetation. As with other agricultural applications, it is desirable to prevent the introduction of highly mineralized industrial wastes into the waste waters that are to be reclaimed.

Normally, the total dissolved solids for water to be used for recreational purposes should be less than 2500 to 3,000 ppm. The permissible range for the per cent sodium ratio varies with the total concentration of dissolved solids, and the character of the soil. Seventy-five per cent sodium to 50 per cent is a doubtful range. High percentage sodium waters may cause the soils to seal and reduce percolation rates and interfere with the root growth of plants. The amount of boron should not exceed 2.75 ppm, the maximum concentration that can be tolerated by most plants used for recreational purposes.

For a golf course, a well-oxidized effluent may be the desirable minimum treatment. Storage of sewage effluents so that the detention period equals 30 days or more should assure high bacteriological quality. Hence, it may not be necessary to chlorinate an effluent receiving sufficient storage in an oxidation pond. However, it is undoubtedly wise to maintain a water of a high bacteriological quality. No disease transmission or other nuisance conditions have been reported as resulting from the employment of reclaimed water in any of the golf courses herein discussed. It has not been uncommon to find public health authorities requiring chlorine contact chambers with total contact time of 30 minutes, and chlorine residuals of at least 0.1 ppm, as a final step before admitting the reclaimed waste water to the distributing system. In short, water meeting the bacteriological standard of drinking water has been demanded.

Chlorination will have no adverse effect on greens and fairways unless substitution of an excessively high chlorine dosage is made for failure to provide adequate contact time. The result will almost certainly be a bleaching and yellow streaking of the grasses.

There has always been the question as to whether extensive chlorination of a waste to be used for golf course irrigation is necessary and, if chlorination is not practiced, would it be possible for certain diseases normally water borne to be so transmitted by the usual spray irrigation methods.

An explanation of the basic research undertaken in an attempt to answer this question is beyond the scope of this paper. The work involved the use of a waste water containing 450,000 coliform organisms per ml, and a two-stage separation-concentration technique to collect air samples and subsequently to detect bacterial pollution. A standard molecular filter provided selective detection of the coliform organisms.

The results clearly indicated that coliform organisms are able to be airborne only in moisture droplets. All air samples taken within the zone of mist, resulting from the application of the sewage by means of a rotary sprinkler head, indicated positive results. Thus, a possible health hazard exists within this area, and only within this area. Therefore, the present practice of requiring a waste to be coliform-free when leaving a sewage treatment plant is warranted, except when prolonged storage is available or when players are protected from direct contact with irrigation waters by use of such waters during off-hours.

Throughout the southwest, there are many golf courses that are successfully being irrigated with reclaimed waste water. A recognized leader in the practice has been the U. S. Navy, with golf courses at the El Toro Marine Air-Base near Santa Ana, the Camp Pendleton Marine Base near San Diego, the Nebo Marine Supply Depot near Barstow, and the Naval Ordnance Test Station near China Lake, all in California.

The El Toro Marine Air-Base reclaims water from two trickling filter plants of 1.5 mgd combined capacity, but with combined average flow of approximately 0.8 mgd. The chlorinated effluent is pumped to steel storage tanks, and then is repumped through cast iron pipes to the golf course. About 35 per cent of the total flow is used for irrigation and the rest of the effluent is discharged into a surface creek. The water was first used on the golf course in 1948. Having been originally subjected to zeolite softening, the waste water has a high sodium ratio of approximately 75 per cent and total dissolved solids of over 800 ppm. However, this waste water is used satisfactorily for there has been no deleterious effect on the sandy loam soil to which it has been applied, and the growth of the grass has been highly satisfactory. No plant or human diseases are reported traceable to the use of the plant effluent. Besides the cost and difficulty of obtaining water from other sources, such as wells, one of the main reasons for the use of the effluent is that the local well users would be very antagonistic toward the diversion of available ground water for use in golf course irrigation. To satisfy the local farmers, it was found desirable to reclaim this effluent. The golf course is designed so that all valves are underground and can only be turned on or off by the standard-type sprinkler that is inserted into the sleeve outlet of the valve. The irrigation of the golf course is continuous except when play is heavy, and there is very little odor present at the course.

The Camp Pendleton Marine Base has an integrated waste water reclamation program which includes the use of effluent for golf course irrigation, supply of a decorative lake, and recharge to the upstream ground water for re-pumping as the water supply. The effluent is spread upstream from the wells so that much of the sewage treatment plant effluent replenishes the ground water that supplies the Pendleton water supply. The effluent from one sewage treatment plant is discharged into an oxidation pond used as a reservoir. The domestic type sewage receives secondary treatment (trickling filter) and chlorination prior to storage. The effluent from this treatment plant was first re-used on the golf course in July, 1952. Two acre feet per

day are supplied. Analysis of the reclaimed effluent shows an average total dissolved solids content of 700 ppm and an average boron content of 2.2 ppm. There have been no problems with odors, mosquitoes or disease. There have been minor difficulties associated with the presence of psychoda filter flies being discharged through the irrigation system onto the golf course. The irrigated area, including the golf course, is 122 acres. The soil types include sand, clay and silt. The fairways are covered with Bermuda grass and the greens and fairways, in spite of considerable use, are in excellent condition.

At the Nebo Marine Supply Depot, the effluent from the oxidation ponds following primary tanks has been pumped directly to the 35-acre golf course since 1953. The sewage treatment plant flow averages 0.3 mgd, with approximately 0.2 mgd being used for irrigation of the golf course. The remainder overflows into effluent storage basins adjacent to the Mojave River.

Bermuda and perennial rye grasses are grown on the fairways. The greens are covered with bent and the approaches to the greens have redside grass.

There are occasional odors from this irrigation with the oxidation pond effluent. No flies have been reported but there are some mosquitoes where sprinkler ponding occurs. There have been no complaints by users of the golf course except for the odor condition.

A new 50-acre golf course employing effluent from the China Lake Naval Ordnance Test Station sewage treatment plant has been built. This golf course was graded during the fall of 1955, and planting of rye and bluegrass was started in November. The planting of grass in the winter period resulted in poor grass growth. Replanting during spring weather resulted in the establishment of excellent greens and fairways, indicating that the poor winter growth was not related to the use of reclaimed water. The desire to control the coliform count of the oxidation pond effluent was responsible for the initial use of high chlorine dosages which were responsible for some bleaching of the grass. Observations made at a reduced chlorine dosage indicated that coliforms were as adequately controlled as at the high dosage. Unfortunately, the China Lake system does not have a chlorine contact chamber to aid in obtaining a maximum kill with a minimum dosage. Over-irrigation originally resulted in the development of saturated soil areas which interfered with grass growth. A crusty, fine sand is present on the surface of the golf course. The golf course is now in excellent condition and a 5 ppm chlorine dosage is reported to maintain a free chlorine residual of 0.5 to 0.7 ppm in the irrigation water. Up to 2 mgd of waste water were used for irrigation during the first year.

Of the many municipalities that have resorted to the use of reclaimed waste water for golf course irrigation, only a few can be enumerated here. Chief among them is the Flying Hills course at El Cajon, a project which has been subject to considerable study.

On the basis that effluent from the City of El Cajon, California, activated sludge plant would be made available for irrigational use on a proposed golf course, private interests constructed the 18-hole Flying Hills golf course. The course would not have been built had not the effluent been available. In return for the free use of this effluent (except for payment of extra chlorination costs), it has been agreed that the golf course will revert to San Diego County in 20 years.

It was built on a part of a former army airfield and covers an area of over 60 acres. The land was graded and the necessary irrigation system was installed in 1955.

The fairways were seeded with Bermuda grass, the greens were seeded with bent grass, and a blue grass mixture was sown on the approaches. A distribution system using transite and plastic pipe, and Buckner recessed valves for the sprinklers, was installed. Throughout the time the golf course was being constructed, only 3.06 inches of rainfall occurred. Hence, during the establishment of this course almost the entire water requirements were supplied by effluent.

In establishing the grass growths, it was found that the bent grass seed would not germinate on certain greens. Soil and water samples were collected and analyzed and it was found that high conductivities were always present in soil extracts where poor grass germination occurred. In the soils where there was good drainage, minimum salinity was observed and good germination occurred. It was also found that grass grew much better during warm weather than during the cold months of December, January and February. The grounds keeper reported that Bermuda grass established itself within six months with root depths of 14 inches.

Some of the greens had to be rebuilt and replanted. Upon replacing the saline soils with a sandy soil, the bent grass was able to establish itself with a minimum of difficulty. In addition to placing sandy soil, it was found desirable to utilize within the greens agricultural drain tile placed in the form of a Y. These tiles were covered with gravel to assure good drainage. It should be noted that the sewage effluent, with a conductivity of 1400 micromhos per cm, could not satisfactory leach the adobe soils to the point where good general germination of the relatively intolerant crop of bent grass could occur. This same effluent, however, has been very adequate where more permeable soils were used or where the more tolerant Bermuda grass has been grown.

A test green was selected on which separate areas were irrigated with fresh water and with reclaimed water. Soil samples were obtained frequently from both sections of the green over a one-year period. There was superior root structure in the portion of the green irrigated with reclaimed water. The salinities of the soil-water extracts from both sections of the green were comparable, and in the range of 2 to 4 millimhos per cm.

It has been found that during the winter, when there is reduced amount of irrigation with sewage effluent, it is desirable to add approximately 40 lb of ammonium sulphate per acre as a supplemental nutrient. During the summer, no supplementation has been necessary.

As indicated above, reclaimed water is supplied by the El Cajon activated sludge plant. The effluent from this plant is discharged into a creek. About one mile downstream from the plant, a diversion weir and gate diverts creek water into a small storage reservoir. Pumps then distribute the flow into the distribution system.

The California State Department of Public Health has required a 2 ppm chlorine residual to be maintained at the discharge end of the chlorine contact chamber located at the treatment plant because it was believed that this chlorine content would provide a measurable residual at the inlet to the storage reservoir. The chlorine contact chamber has a theoretical detention time of about 30 minutes. The rate of chlorination varies from 5.5 to 11.0 ppm, with the average being about 7.0 ppm. The average flow is about 0.9 mgd. The El Cajon sewage treatment plant pays for the first 20 lb of chlorine dosage and the remainder of about 35 lb is paid for by the Flying Hills golf course management.

During dry, summertime conditions, the 18-hole course receives approximately 0.3 MG 5 days per week.

Each portion of the golf course is irrigated on the average of 3 times week. This irrigation period for each application varies from 30 to 45 minutes. Greater irrigation of the greens is provided for by overlapping sprinklers. During rainy weather, in the winter, this irrigation schedule is reduced.

To date, there have been no odor or other complaints reported from the players or operators of the golf course.

The 9-hole municipal golf course of Carlsbad, New Mexico, was started in 1953. Effluent from a 2-mgd trickling filter treatment plant is utilized for irrigation of this 30-acre golf course. It is discharged through a 1-mile pipe line into an earthen reservoir. Distribution to the golf course is by asbestos-cement and steel laterals. The effluent, when not employed by the golf course, is diverted to the Pecos River. Approximately 1.5 mgd are applied during 7 months of the year for irrigation. The irrigation system is marked with signs indicating non-potable water. Each sprinkler has its own valve and the valves are marked with aluminum and yellow paint. There have been no odors, flies, mosquitoes or disease problems associated with the irrigation procedure.

The only alternative water supply for irrigation of the golf course consists of river water during off-peak irrigation periods. However, this off-peak irrigation water is not dependable as it is not available in sufficient quantity. The depth to ground water is thirty-five feet. The rainfall in the Carlsbad area is only 5 in. per year. In the New Mexico area, it normally takes about two years to establish a good growth of Bermuda grass on fairways. At Carlsbad the fairways were established in about six months, because of the superior irrigation value of the effluent.

The original water for the Jal, New Mexico, municipal water system is derived from wells and the domestic type sewage is treated by means of primary sedimentation followed by oxidation ponds. The treatment plant was built in 1950 and the flow averages 0.15 mgd from approximately 2000 persons.

The effluent was first reclaimed in 1952, and is all used on the municipal golf course. The water hydrants have conventional outlets and are connected to rubber hoses with sprinklers on the ends. These outlet hydrants are marked so as to indicate that they supply non-potable water. There are no fly, mosquito, or health problems associated with the reclamation of the effluent. Slight odors occurred in the sprinkling system when waste water was first run into the sprinklers because of long detention period in an enclosed elevated steel storage tank. The soil is a sandy clay.

At Eagle Pass, Texas, the Country Club golf course is kept green by pumping from the last lagoon of the treatment plant. There is no odor.

At Prescott, Arizona, a new 18-hole golf course is being irrigated with sewage treatment plant effluent. The effluent is carried 30,000 ft through a gravity-flow line and is then distributed under pressure to the golf course sprinklers. The effluent quality has been found satisfactory to support the bent grass on the greens, and the mixture of Kentucky Blue, Rainier Fescue, Rye, and Chewings Fescue on the fairways, aprons, and tees. The system can supply a maximum of 0.4 mgd.

At Santa Fe, New Mexico, 3 to 4 acre-feet per year of effluent from the city's high rate trickling filter plant are being used to irrigate a golf course. There are approximately 20 acres of irrigated area on the golf course. The

soil is a sandy, clay adobe type. There is no other water supply available for irrigation. The ground water which is used for domestic supply is approximately 250 ft below ground level. The waste water is transported three-fourths of the way by open canal. The total distance is approximately 3.5 miles from the treatment plant to the golf course. It is reported that the effluent has desirable fertilizer characteristics. There have been no odors, flies, or mosquito problems associated with the reclamation of the effluent.

At Los Alamas, New Mexico, an 18-hole golf course utilizes 0.23 mgd of chlorinated effluent from the city's trickling filter plant during the period March to November, except when there is rainfall. There have been no odor, fly, mosquito, or other problems associated with this waste water use. The area of the golf course is approximately 100 acres. The ground water is at a depth of more than 2,000 feet. It is costly to pump this water to the high plateau at Los Alamos. Hence, it is doubtful that a golf course could be supported there unless the available waste water were reclaimed. It is reported by the operators of the Los Alamos golf course that the reclaimed water loosens and increases the fertility of the soil. The quality of the reclaimed effluent is excellent.

Reclaiming the waste water for the golf course as well as for other purposes has made possible an annual saving of $20,000 in the operating expense for the pumping and the maintenance of the well field. Water reclamation nas prevented depletion of the water well field and reduction in the ground water level. The capital requirements for the construction of additional wells and a larger pipe line would have increased the cost of the installation. Thus, as a result of waste water reclamation, it has been possible to reduce the cost of the original plant installation, reduce the operating expenses, eliminate surface water pollution of the basin and the surface stream, and conserve the existing ground waters.

A well-known hotel at Las Vegas, Nevada, operates its own activated sludge type treatment plant which reclaims the resort waste for direct irrigation of the golf course. About 0.6 mgd is used for irrigation in summer, supplemented by well water as needed. In the winter time, only effluent is used. The effluent is transported in clay pipes from the treatment plant to six decorative lakes on the golf course that act as hazards and distribution reservoirs. These lakes are periodically drained in order to recover the golf balls, remove sludge from the bottom and clean out algae. Ducks, mudhens and geese are kept in these decorative lakes. Besides water fowl, the ponds are reported to have bass, catfish and carp in them. Asbestos-cement pipe is used in the irrigation system.

It is reported that the reclaimed water is more beneficial for plant growth than well water. Gypsum is added to the surface of the golf course in order to counteract the approximate 100 per cent sodium ratio in the irrigation water.

There have been no fly or mosquito problems reported with the re-use of this effluent.

This paper has been prepared with the hope that a recitation of successful past performances of reclamation projects involving the irrigation of golf courses with waste water will stimulate others to follow suit. The need for conserving potable waters is becoming more and more acute in many sections of the country, and the time is just about at hand when a once-used water cannot be thrown away. Experience begets progress, and the use of sewage effluent will be better accomplished only when the experience and record of prior practical application is available for guidance.

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A BALANCED ECOLOGICAL SYSTEM FOR SPACE TRAVEL

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ABSTRACT

The present paper discusses the nature and requirements of a sustenance system. Its components include a stabilization process for urine and feces, a reclamation process for recovery of potable water from body wastes, and a photosynthetic gas exchange process for production of oxygen and food from algae culture. The system described offers interesting research opportunities for sustaining man in a "closed" environment.

Man stands poised to make his first journey into space. Once departed from Mother Earth, he will travel through alien and hostile environs. To survive, man must carry with him an environment identical to the one left behind. The air he breathes, the food he eats, the water he drinks, the temperature he experiences, all must conform to earth's standards. Only the slightest variations will be tolerated.

The purpose of the present paper is to outline in broad terms the requirements imposed by man upon his sustenance system. The discussion is organized within the framework of the scheme outlined in Fig. 1. It is hoped that the paper will contribute to the formulation of the research and development objectives needed to perfect such a system.

For trips of a few weeks duration, tanked water and oxygen and food in dehydrated forms can be carried from earth's abundant stores. However, for long-term space operations, provision must be made to derive the

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physiological necessities from the environment within the space vehicle. Conservation of environmental mass will make mandatory some type of a closed ecological system kept in motion by a source of continuous energy. Conceivably, such a system will involve a carbon dioxide-oxygen exchange between human and plants, waste reutilization, and the growth of plants for human consumption. Items on the original inventory will be used over and over for the continued sustenance of man.

Many sustenance systems have been proposed, a few of which have appeared in publication. While differing in details, most are similar to the system outlined in Fig. 1. This scheme follows a functional pattern which for research and development purposes groups the individual operations and processes in general areas of attack. The scheme is not meant to be a specific, but, rather, one which is sufficiently broad to allow for the inclusion of almost any system devised.

The Human and His Environment

If plants are used to replace oxygen in man's environment then it is logical to expect that an effort will be made to utilize surplus plant growth as food. Fig. 2 is a gross daily materials balance for a sustenance system in which a man-unit subsists on a diet of algae. The pictorial representations are only symbolic, and, probably bear little relationship to the equipment and microorganisms employed in any functional system which will ultimately evolve. Perpetuity is guaranteed by the fact that there is no loss of environmental mass from the system. For any other set of assumed conditions a similar balance can be demonstrated.

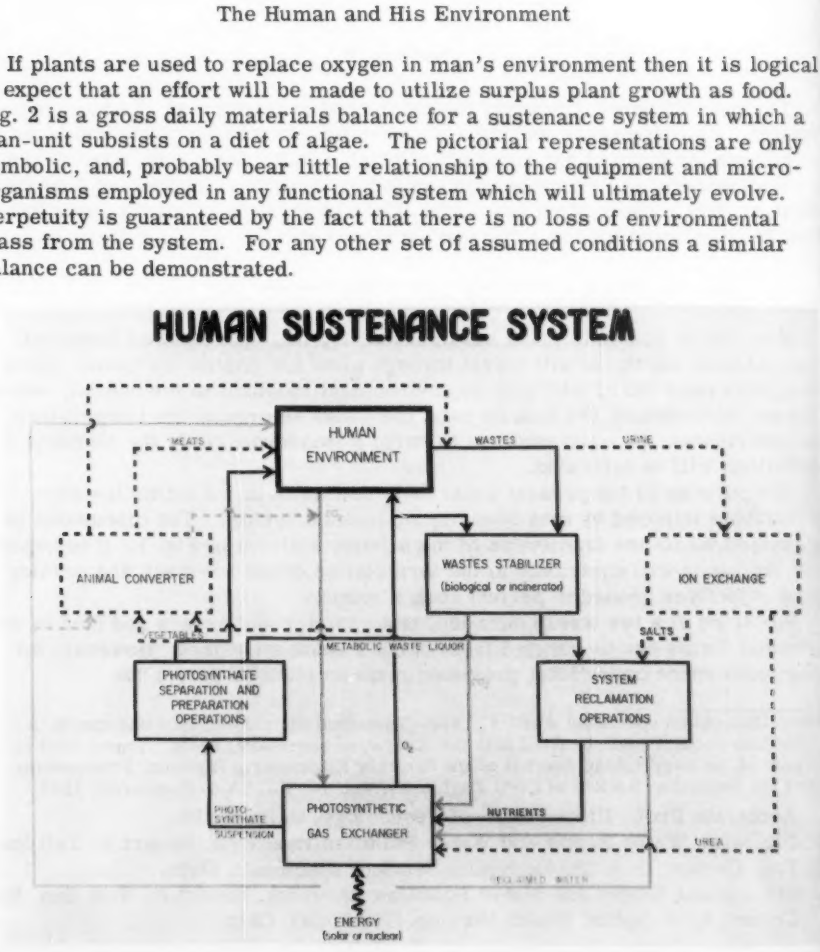

Fig. 1

Man is essentially a machine. Like all machinery his fuel requirements depend upon the work he performs. A 25 year old male, 67 inches tall and weighing 146 pounds, performing light work will require an energy intake somewhere in the neighborhood of 2,800 kilocalories per day.(1) If the algae he consumes is Chlorella which has an average heat of combustion of 5.5 kilocalories per gram,(2) approximately 510 grams (dry weight) would satisfy his daily energy requirements. Like most foods not all of the algal cell is digestible. It is generally believed, however, that most of the cell can be readily digested.(3,4) Assuming, then, all but 5 per cent of the algae consumed is assimilated and is available as energy, the total weight of algal solids required for food purposes would be 537 grams. This figure controls the specifications of all the major components of the sustenance system.

Carbon dioxide, water, and urea constitute the major end products of human metabolism. Dried Chlorella cells grown under favorable conditions contain about 50 per cent proteins, 30 per cent carbohydrates, 15 per cent lipids and 5 per cent ash.(2) Based on these values, 764 grams of oxygen per day are required to metabolize completely the carbon, hydrogen, and nitrogen assimilated by the human system. At one milliliter of water per kilocalorie of food assimilated, the water intake would be 2,800 grams.(1) It is assumed that 1,800 grams will be ingested with the algae and the remainder consumed as drinking water.

Considerable thought has been given to the problem of providing the space man with a proper air-blanket. Although the atmospheres of earlier space cabins may deviate somewhat from earth's standards,(5) those coming later, no doubt, will carry atmospheres conforming closely to that of the earth. A temperature in the neighborhood of 70° F and a relative humidity ranging from 30 to 40 per cent offers optimum comfort.(6)

GROSS DAILY MATERIALS BALANCE FOR HUMAN SUSTENANCE SYSTEM

(PER MAN-UNIT)

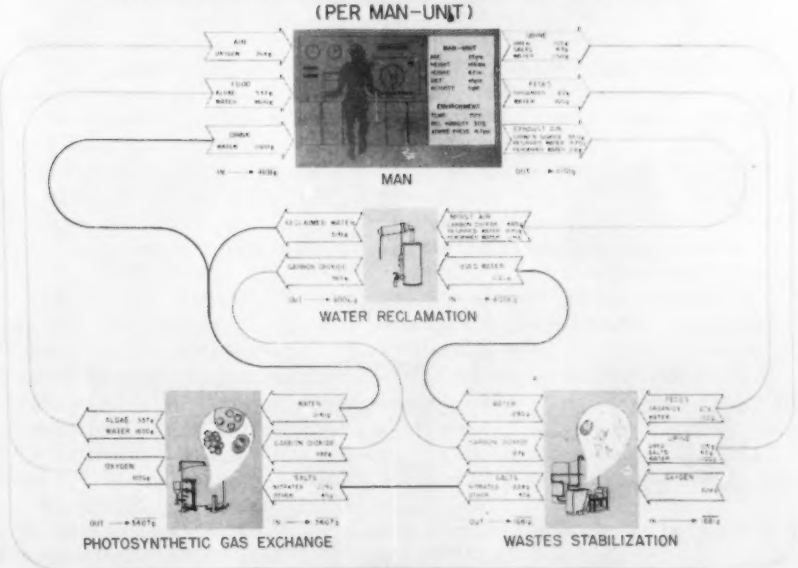

Fig. 2

The wastes of man are primarily fecal, urinary, and respiratory. According to the balance in Fig. 2, the space man will expire daily 865 grams of carbon dioxide and 1,570 grams of water. The latter was computed on the basis of an average ventilation rate of 30 liters of air per minute,(7) the air inspired having a relative humidity of 30 per cent and a temperature of 70° F, and the air expired being saturated and at body temperature. The water accompanying the feces and that excreted as urine could be expected to be of the order of 100 grams and 1,100 grams respectively.(8) The remainder of the total water discharged (which is equal to the water intake plus the metabolic water) was assumed to be perspiration. Although, carbon dioxide and water constitute a major portion of the wastes discharged to the atmosphere, small quantities of pollutants resulting from flatulence and excretions of the sebaceous and sweat glands would be found there also.(9) Cabin air, with or without prior treatment to remove certain waste products and/or to enrich further the carbon dioxide concentration, could be fed to the photosynthetic gas exchanger.

Waste Stabilization and Reclamation Operations

Waste reutilization is a vital part of any closed ecological cycle. However, with the exception of urea, those wastes which are organic must be converted to inorganic forms prior to their utilization by plants. Conversion requires at least a partial oxidation.

Fig. 3 contains gross daily materials balances per man-unit for the two types of waste stabilization trains. The unusual character of the wastes is to be noted—27 grams of organic fecal solids, 105 grams of organic urine solids (chiefly urea), 43 grams of inorganic salts (largely chlorides) and about

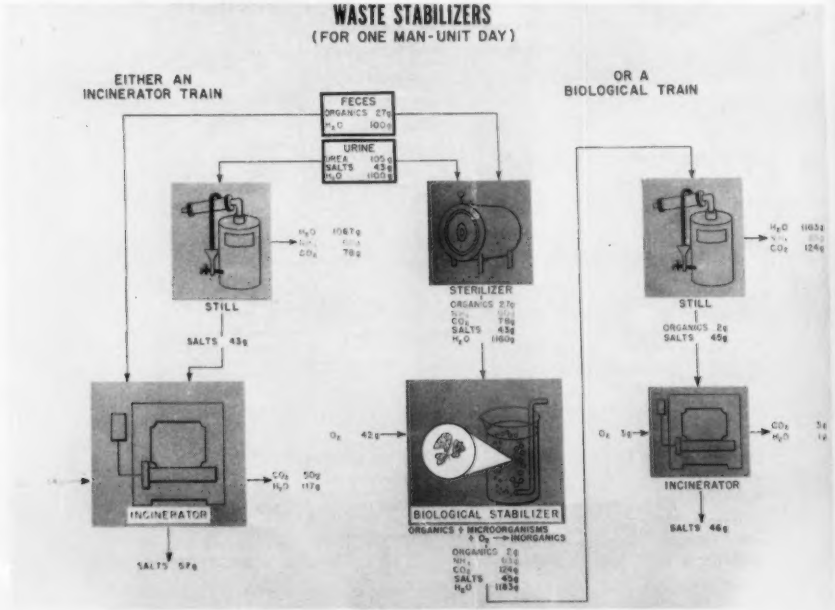

Fig. 3

1.2 liters of water. The composition would be altered by the inclusion of any waste resulting from food preparation, ablutions, etc.

Chemical oxidation is often accomplished most conveniently by combustion. Where combustion is used as the principal stabilization operation, it might be practical to incinerate only the fecal solids and bypass the urine to the photosynthetic gas exchanger. Urea is utilized by many algae as a nitrogen source. In such an arrangement the urine may have to be treated first by a sequence of sterilization and desalting operations.

Stabilization of both fecal and urinary solids or of fecal solids alone may be achieved with the use of pure or mixed cultures of aerobic microorganisms. Displacements from the culture would include carbon dioxide, biological growth, and metabolic waste liquor. The carbon dioxide would be fed to the photosynthetic gas exchanger and the growth and metabolic waste liquor treated with appropriate reclamation operations.

The term "system reclamation operations" used in Fig. 1 was devised to include those operations which, for an ecological cycle completely closed, would be ancillary to the major components of the system. Such operations would consist of distillation, incineration, condensation, and possibly, adsorption and chemical precipitation.

In the case of short-term space operations where a closed cycle would not be economical weight-wise, the reclamation operations might assume a major importance. Calculations based on the information listed in Fig. 2 indicate that whereas urine reclamation will save about 1,000 pounds per man-year in weight at take-off, the total reclamation of feces would save only about one-tenth of that, or 100 pounds. It would appear, therefore, in the case of space operations of intermediate duration, that it would be more feasible to reclaim water and nutrients from the urine and to package and store all feces.

Photosynthetic Gas Exchanger

Photosynthesis is the key process in any ecological cycle of which man is part. Energized by radiant energy, photosynthesis converts carbon dioxide, water and inorganic salts to oxygen and vegetable food materials. In a sustenance system similar to the one outlined in Fig. 1, the photosynthetic process would take place in the photosynthetic gas exchanger.(10)

All organisms containing chlorophyll are capable of photosynthesis. However, to date, only the algae have been seriously considered for use in a gas exchanger.(10,11,12) Due to their microscopic size, algae lend themselves to manipulation under conditions that promote the greatest photosynthetic efficiency. Furthermore, unlike the higher plants where a sizeable portion of the plant structure is indigestible, algae are almost entirely digestible.

In Fig. 2 a materials balance is struck for a gas exchanger employing Chlorella as the photosynthate. The utilization of all the carbon dioxide produced by human respiration and the total oxidation of wastes will result in the evolution of 1,070 grams of oxygen, the amount required to sustain such respiration and oxidation. Furthermore, the weight of algae produced, 537 grams, is the exact quantity consumed each day by the space man. In the same manner, a balance can be demonstrated for those systems in which the wastes are only partially oxidized.

On earth, gas exchange is most often accomplished simply by bubbling gas through a liquid. Such an arrangement would not be satisfactory in a space

vehicle where gravitational forces may be experienced which range from zero to several G's. In all likelihood, equipment ultimately developed for this purpose will function independently of gravity.

A tentative design of a photosynthetic gas exchanger is presented in Fig. 4. Briefly, the exchanger consists of irradiated culture tubing through which a suspension of algae and compressed air is pumped, turbulence being induced by pipe friction. Upon leaving the irradiation tubing the suspension flows through a stationary centrifuge where the gas phase enriched with oxygen is removed. After a withdrawal of a portion equivalent to the increment of algal growth, the suspension is recharged with make-up water, nutrients, and compressed air and returned to the irradiation tubing. Materials out of which the exchanger is constructed are available on the market. Note should be made of the estimated weight and cubage. Obviously, reduction in both would have to be accomplished before such equipment would be practical for space flight. The design is based on broad principles and is not the result of research and development. The idea is presented here only because it suggests a possible solution to the problem of gas exchange independent of gravity.

Photosynthate Separation and Preparation Operations

Prior to human consumption, the algae would be harvested from the suspension and prepared in a palatable form. Most likely, separation can be accomplished satisfactorily with a centrifuge. Water and the metabolic waste products in the liquor discharge could then be made available again to the system with appropriate reclamation operations.

As stated earlier, dried Chlorella cells contain about 50 per cent proteins, 30 per cent carbohydrates, 15 per cent lipids and 5 per cent ash. The protein

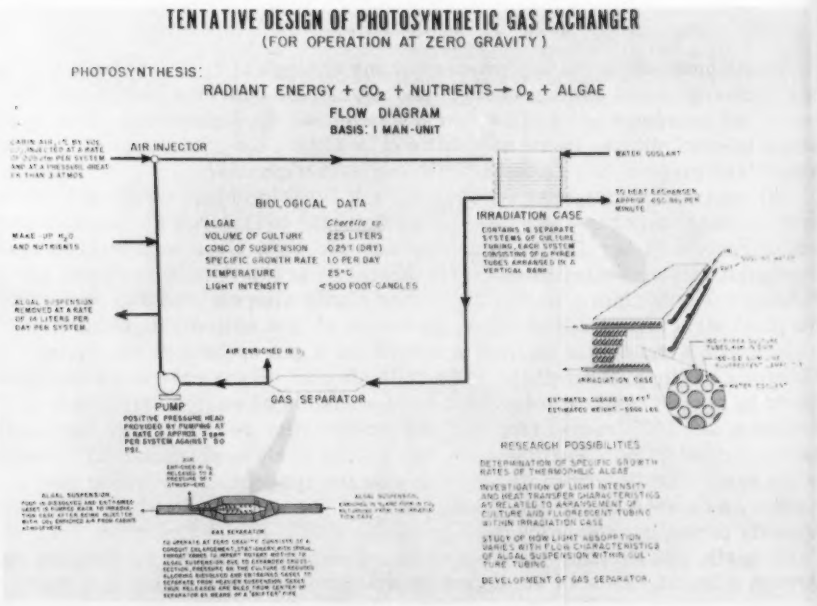
TENTATIVE DESIGN OF PHOTOSYNTHETIC GAS EXCHANGER
(FOR OPERATION AT ZERO GRAVITY)
PHOTOSYNTHESIS:
RADIANT ENERGY + CO_2 + NUTRIENTS → O_2 + ALGAE
FLOW DIAGRAM
BASIS: 1 MAN-UNIT
AIR INJECTOR
BIOLOGICAL DATA
ALGAE Chorella sp.
VOLUME OF CULTURE 225 LITERS
CONC OF SUSPENSION 0.25 (DRY)
SPECIFIC GROWTH RATE 1.0 PER DAY
TEMPERATURE 25°C
LIGHT INTENSITY < 500 FOOT CANDLES
IRRADIATION CASE
MAKE UP H_2O AND NUTRIENTS
ALGAL SUSPENSION REMOVED AT A RATE OF 1/4 LITERS PER DAY PER SYSTEM
GAS SEPARATOR
PUMP
POSITIVE PRESSURE HEAD PROVIDED BY PUMPING AT A RATE OF APPROX. 3 cfm PER SYSTEM AGAINST 50 PSI.
RESEARCH POSSIBILITIES
DETERMINATION OF SPECIFIC GROWTH RATES OF THE PHOTOSYNTHETIC ALGAE
INVESTIGATION OF LIGHT INTENSITY AND HEAT TRANSFER CHARACTERISTICS AS RELATED TO ARRANGEMENT OF CULTURE AND FLUORESCENT TUBING WITHIN IRRADIATION CASE
STUDY OF HOW LIGHT ABSORPTION VARIES WITH FLOW CHARACTERISTICS OF ALGAL SUSPENSION WITHIN CULTURE TUBING
DEVELOPMENT OF GAS SEPARATOR

Fig. 4

appear to be suitable for human nutrition for they contain adequate amounts of all the essential amino acids except those containing sulfur.(13) Furthermore, the cells are relatively rich in vitamins.

Dried Chlorella has a vegetable-like flavor, resembling that of raw lima beans or raw pumpkin.(14) Although salad and soup preparations made from fresh Chlorella have been reported to be palatable,(13) it is doubtful that these preparations would be acceptable as a steady diet. Possibly, algae can be converted into a variety of interesting foods using a combination of such processes as pigment extraction, hydrolysis, fermentation, curing, etc.(15)

Meat could be provided in a sustenance system by animals feeding on algae. However, animals consume a certain quantity of food to furnish the energy required for growth. An animal feeding on a pound of algae would produce somewhat less than a pound of meat. Furthermore, man considers some parts of the meat animal unappetizing. For these reasons, the algae-to-animal conversion would be relatively inefficient. Based on the meat parts normally eaten by man, such a conversion could be expected to be only 10 to 20 per cent efficient.(15) If food animals are included in a sustenance system, the losses resulting would have to be compensated for by increasing the capacities of the other components of the system. An animal converter would not be practical for any but the longer extraterrestrial operations.

Other Applications

The application of sustenance systems is not confined to space vehicles. Once he has conquered space, man can be expected to establish semi-permanent scientific outposts on adjacent planetary bodies. Such stations will probably be manned by crews considerably larger than those of space vehicles, making the problem of supply even more formidable. Sustenance systems may provide a solution to the problem. With the tools that nuclear energy can furnish, it is possible that most of the elements used in the system can be produced on the site.

In the event of a world-wide nuclear holocaust, such systems may prove to be the key to human survival. Sizable segments of the world's population might find refuge in underground cavities provided with artificial environments on a scale much larger than those contemplated for space vehicles. Communities thus isolated would have a greater chance of survival.

From the microcosm to the macrocosm, however, the principles involved are the same. Any sustenance system must include man, plants, and an energy source. The interrelationship between the three has been established. What is lacking is the biotechnology needed for application.

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INDUSTRIAL WASTE DISPOSAL TAILORED TO STREAM FLOW[a]

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ABSTRACT

Recognizing the technical and economic limitations of waste treatment in maintaining satisfactory stream conditions during drought season, two possibilities for more efficient utilization of water resources hold promise. Either the stream flow should be regulated to make a higher level of total flow usable; or the industrial waste discharge should be regulated, tailored to the varying pattern of stream flow. A detailed case analysis of the latter, regulating release from waste storage lagoons in accord with the varying waste assimilation capacity of the stream, indicates industrial expansion potential 10 to 50 times that possible under drought flow conditions.

INTRODUCTION

Water is the resource of major significance in the United States today, particularly in relation to community and industrial growth. As competition among multiple users intensifies, ways and means for more efficient utilization of this precious resource must be sought. In the rapidly changing pattern of multiple water use and development, satisfactory and economical waste disposal is frequently the key factor in the location of a new industrial plant. It also weighs heavily in the decision to expand, curtail, or abandon an existing site. In the current decade of expansion the United States has been quite thoroughly combed and re-combed by one industrial group after another in search for industrial locations with favorable water resources. Few so-called

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a. Paper presented at Meeting of National Council for Stream Improvement (of Pulp, Paper and Paperboard Industries) Inc., White Sulphur Springs, W. Va., Aug. 7, 1958. (Technical Publication N.C.S.I.)

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good run-of-the-river natural sites remain. In fact, under the pressure for higher stream quality requirements many sites now occupied are rapidly approaching the limit of waste assimilation capacity or are being seriously encroached upon by the impact of other river developments. It is the purpose in this discussion to explore two promising possibilities for more efficient utilization of water resources for the increasingly difficult and expensive problem of industrial waste disposal.

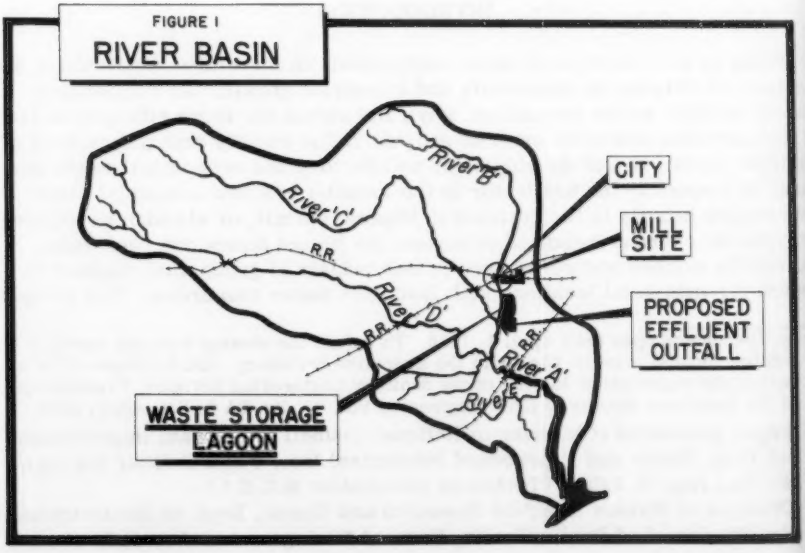
In the past, the conventional method of meeting the increasing needs of community and industrial waste disposal has been to restrict growth to the minimum water resources available under drought conditions and to press for higher and higher degree of treatment of wastes. Treatment will always play an important role in waste disposal, but it must be remembered there is no such thing as one hundred per cent treatment or recovery. There are technical and economic limitations, particularly if treatment is required to meet the burden of maintaining water quality conditions during the minimum drought flows.

In the natural setting, water is a highly variable resource, ranging from extremes of flood to long protracted periods of low flow during the drought seasons. To limit community and industrial growth to the minimum flows available obviously means that during periods of higher flow valuable water resources are wasted. This is inefficient use. In the sense of living within the framework of the natural drought pattern and the technical and economic limitations of waste treatment, many areas of the United States are already over-developed and the outlook for future growth and expansion under this concept is indeed dismal.

The two promising possibilities for more efficient utilization of water resources, by this time, must be self-evident. Either the stream flow should be regulated to make a higher level of the total flow usable, or the waste discharge should be regulated, tailored to the varying pattern of the stream flow.

FIGURE 1

RIVER BASIN



using not only the minimum but the whole range of flow. Stream flow regulation is not entirely a new concept. It is well accepted as a means of flood alleviation. The concept of drought alleviation, however, is only recently appreciated. If excess water during the flood season is stored for release during the dry weather season it is feasible in many instances to assure a dependable stream flow several times greater than that under natural uncontrolled drought yield. This minimizes the risk of water shortage, eases the burden of waste disposal, and permits a much higher level of community and industrial growth, benefiting all water users along the entire course of the stream. By its nature, stream flow regulation involves the concept of multiple water use and, in general, necessitates the pooling of interests among all water users in the basin in order to insure the economic feasibility of the comprehensive development required. This entails statesmanship, long range planning, and broad cooperation, but in looking ahead to the future needs this approach will bring rewards.

A Case History

A study undertaken this past year deals with the second approach, regulation of waste discharge to take advantage of the natural variations in stream flow. In contrast to stream flow regulation, this procedure is within the capacity of an individual mill to pursue, without necessity for joint action in cooperation with others. The basin involved, comprising approximately 4,860 square miles, lies in the Piedmont and Coastal Plains (Fig. 1), typical of many of the streams discharging into the Atlantic and Gulf Coast. Much of the drainage area is timbered and the lower reaches of the main river are bordered by extensive swamp lands.

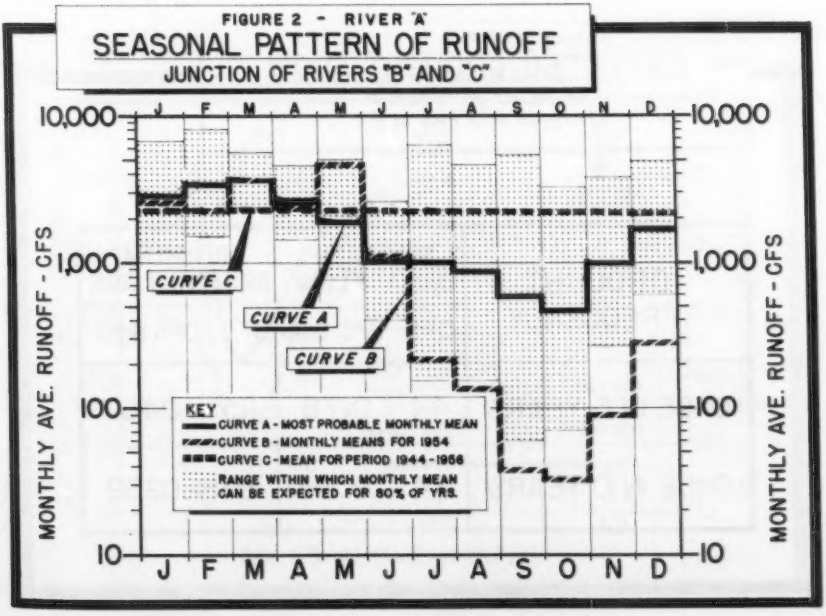


FIGURE 2 - RIVER 'A'
SEASONAL PATTERN OF RUNOFF
JUNCTION OF RIVERS "B" AND "C"
J F M A M J J A S O N D
10,000
1,000
100
10
MONTHLY AVE. RUNOFF - CFS
CURVE C
CURVE A
CURVE B
KEY
CURVE A - MOST PROBABLE MONTHLY MEAN
CURVE B - MONTHLY MEANS FOR 1954
CURVE C - MEAN FOR PERIOD 1944 - 1956
RANGE WITHIN WHICH MONTHLY MEAN CAN BE EXPECTED FOR 80% OF YRS.

An existing mill is located on the tributary River "B" which is subject to extreme droughts, with monthly average discharge declining to as low as 1.0 cubic foot per second. Below the mill site and the junction with River "C" are extensive areas suitable for the construction of lagoons. With drought flow as low as 1.0 cfs. direct discharge to the river even with the highest known degree of treatment would not provide any opportunity for expansion at the present mill site. The question posed is: Shall this mill site be abandoned, or what are the potentialities for expansion here with regulated waste discharge through the construction of lagoons with an effluent outlet at the head of River "A"?

While drought flows are very severe, the normal runoff available is good. Fig. 2 shows the seasonal pattern of runoff at the junction of Rivers "B" and "C" at the head of River "A". The most probable monthly average discharge considering each month of the year independently has been determined from a statistical analysis of the discharge records for the period 1944 - 1956, from which the general seasonal pattern of runoff emerges as shown by Curve A. The variation of any month from year to year is great and approaches a logarithmically normal distribution. The shaded belt about the most probable is the range within which monthly average discharge for specific months of the year can be expected for 80 per cent of the years. Referring to Curve A, high runoff normally occurs during the winter-spring season at 3,500 cfs. and low runoff through the summer-fall season with normal monthly flow of 470 cfs. in October. The seasonal pattern for any specific year, however, may deviate considerably from this general pattern, as not all months through a year will experience runoff of the same probability of occurrence. For example, Curve B shows the monthly hydrograph for the specific year 1954, generally recognized as a year of severe drought. While the winter-spring runoff was high for 1954 the monthly average discharge declined to 42 cfs. for

FIGURE 3

EXPECTED DROUGHT FLOW

AT HEAD OF RIVER "A"

(DRAINAGE AREA 2465 Sq. mi)

DROUGHT FREQUENCY	MINIMUM DAILY FLOW		MINIMUM MONTHLY AVE	
	CFS	CFS Sqmi	CFS	CFS Sq.mi
ONCE IN 5 YEARS	44	.0178	115	.0467
ONCE IN 10 YEARS	24	.0097	59	.0239

September and to 34 cfs. for October, with a minimum daily average falling as low as 19 cfs.

Further to define the probabilities of occurrence of severe droughts statistical analyses were made of the minimum daily average and the minimum monthly average discharges occurring in the summer-fall warm weather period, June through November, of each year. Considering the short period for which the record is available, the distributions reasonably follow the theory of extreme values, from which summary of drought severities was determined as shown in Fig. 3. On the average in the long run once in 5 years it can be expected that the minimum daily average at the head of River "A" will decline to 44 cfs. and the minimum monthly average to 115 cfs.; and once in 10 years the minimum daily average declines to 24 cfs. and the minimum monthly average to 59 cfs.

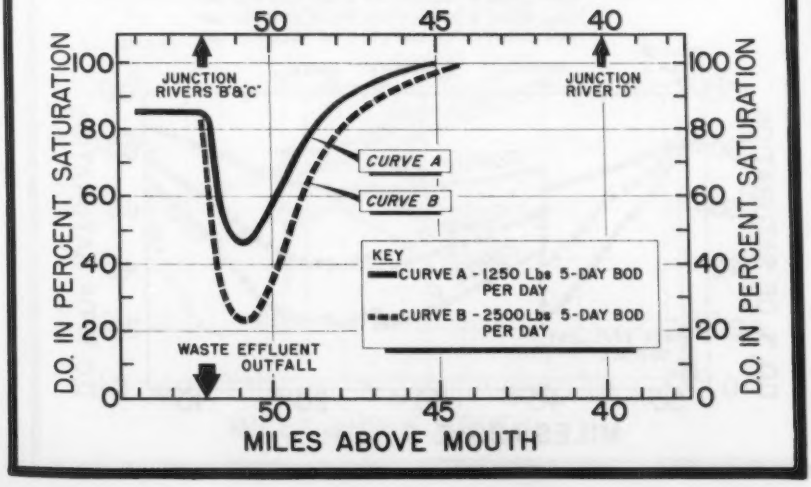
If mill capacity had to be tied to these drought flows, opportunity for expansion is indeed very limited. Referring again to Fig. 2, it will be noted that the general level of runoff is quite high with an average for the entire period of record of 2,150 cfs; and even during the drought season, many years the stream discharge exceeded 1,000 cfs., ranging as high as 5,000 cfs. To restrict industrial development to the minimum drought flows expected such as 115 cfs or less is obviously inefficient utilization of the total water resources available at this site.

This led to the investigation of the total annual waste assimilation capacity of River "A", assuming that full advantage could be taken of the monthly average discharge from month to month throughout the year by regulated discharge of waste from storage lagoons. Knowing the ultimate annual waste assimilation capacity of the river system and the nature of variation of this capacity from year to year provides a rational basis for judging whether to abandon

FIGURE 4 - RIVER "A"

COMPUTED DISSOLVED OXYGEN PROFILES

DROUGHT CONDITIONS, 115 CFS, 30 °C



the site, to expand the mill and to what extent, and to evaluate the relation of size of mill capacity to lagoon storage requirements and the degree to which reliance should be placed upon waste treatment.

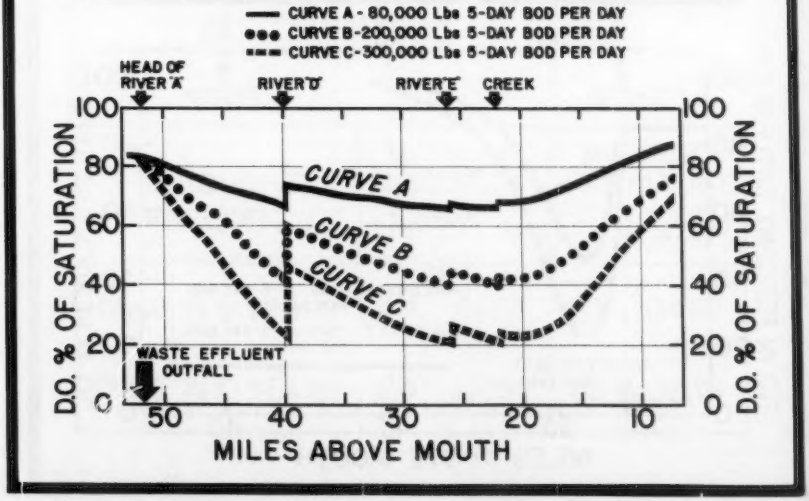
Stream classification for River "A" prescribes dissolved oxygen to be maintained at a level of 4 parts per million. Though the lower basin is sparsely populated, the river is used extensively for sport fishing, and during the herring run for commercial fishing. A number of recreational developments with bathing areas are also located along the lower reaches of the river. Fortunately, detailed hydrologic data, including an unusually good set of channel cross-section soundings along the course of the river, are available, which provided opportunity to determine with reasonable degree of accuracy the time of passage along the course of the channel under various runoff patterns, and the other physical characteristics essential to a quantitative determination of deoxygenation and reaeration. The determination of the annual waste assimilation capacity of River "A" to insure the water quality conditions prescribed by regulatory agencies involved computing an extensive series of dissolved oxygen profiles covering the whole range of seasonal runoff and temperature conditions. In order to keep the computations within reasonable bounds, temperature variation seasonally was divided into three levels: 15° C. as typical of winter conditions for the months December through April; 20° C. typical for the late spring months of May and June and late fall months of October and November; and 30° C. for the warm summer months, July, August and September. In all instances the waste effluent was considered free of any settleable solids subject to deposit and accumulation and to be discharged to the river at Mile 52, head of River "A".

Fig. 4 shows a typical dissolved oxygen profile expected under the extreme once in 5 year minimum monthly average drought of 115 cfs. and warm

FIGURE 5 - RIVER 'A'

COMPUTED DISSOLVED OXYGEN PROFILES

WINTER CONDITIONS, 3500 CFS, 15°C



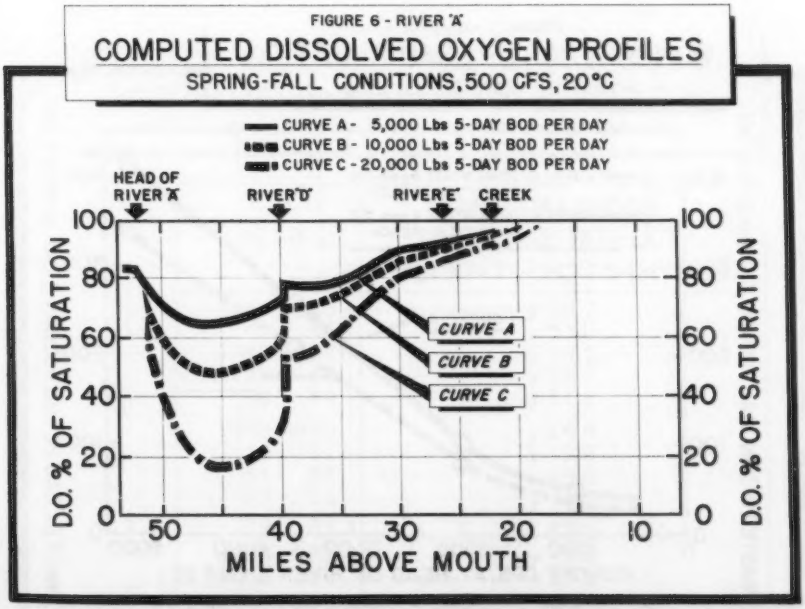
summer temperature of 30° C. Under these conditions a sharp drop in dissolved oxygen is indicated even from relatively light waste effluent loads. Computations show that the allowable waste load to maintain 4 ppm. in the critical reach would be as low as 830 pounds of 5-day BOD per day. Assuming about 80 to 85 pounds of 5-day BOD per ton of production, this would permit a raw waste of only 10 tons per day mill production. Even if so-called complete biological treatment were installed, with an efficiency of 90 per cent BOD reduction, the mill capacity would be limited to about 100 tons per day. Furthermore, under severe drought conditions the dissolved oxygen profile is extremely sensitive and any slight variations in efficiency of treatment or mill production would run the risk of depressing dissolved oxygen below the required standards. This clearly illustrates the point previously made that limiting industrial development to the minimum drought flows available even with reliance upon high degree of waste treatment, does not solve the problem.

In contrast, Fig. 5 shows the computed dissolved oxygen profile under normal winter conditions of 3,500 cfs. and 15° C.; Curve A for a waste effluent loading of 80,000 pounds of 5-day BOD per day; Curve B, 200,000 pounds; and Curve C, 300,000 pounds per day. Under the higher runoff and lower temperature a substantial waste effluent load of about 210,000 pounds of 5-day BOD per day can be handled maintaining 4 ppm. dissolved oxygen in the critical reach.

Fig. 6 illustrates typical dissolved oxygen profile expected during late fall and late spring under relatively low runoff conditions at 20° C.

From the extensive series of computations involving some 40 individually computed dissolved oxygen profiles, it was possible to develop a set of control curves for each of the three seasonal temperature levels, giving the relationship between runoff and corresponding allowable waste discharge to

FIGURE 6 - RIVER 'A'

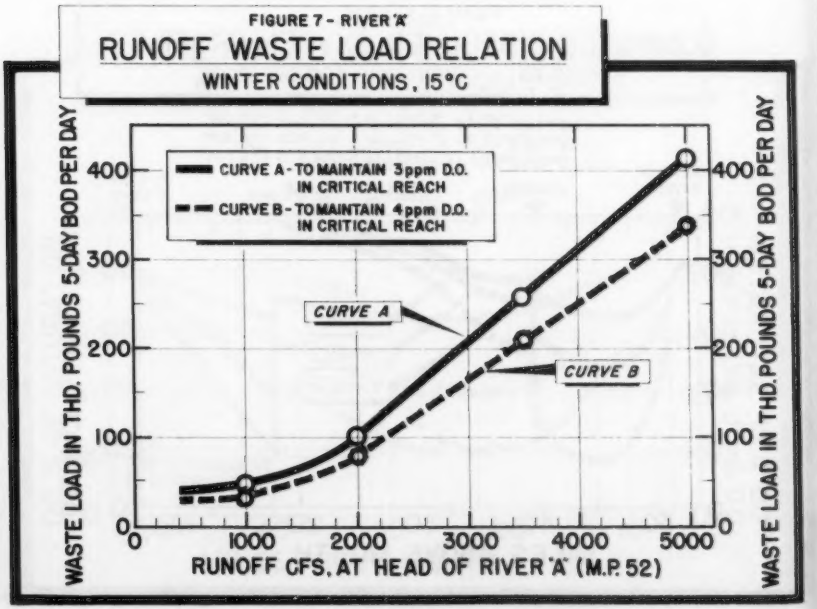


maintain any prescribed dissolved oxygen requirement for the critical reach of the river. Fig. 7 represents such typical control curves for winter temperature covering the expected winter range of runoff 500 cfs. to 5,000 cfs. Curve A gives the allowable waste load to maintain 3 ppm D.0 in the critical reach of the river and Curve B to maintain 4 ppm D.O. Similar control curves were developed for the late fall - late spring conditions and for the hot summer conditions.

With these control curves it was now possible to determine the total annual waste assimilation capacity for each year based upon the actual monthly average discharge of River "A" experienced in the interval November, 1944, through October, 1956. Referring to Fig. 7, at a monthly average discharge of 3,500 cfs. for a winter month, it would be possible to discharge to the river an average daily waste load of 210,000 pounds of 5-day BOD per day and maintain 4 parts per million of dissolved oxygen in the critical reach. It is interesting to note that if water quality criteria would permit 3 parts per million of dissolved oxygen in the critical reach the allowable waste load could be increased to about 260,000 pounds of 5-day BOD per day. Applying the actual monthly average stream runoff for each month to the proper seasonal control curve and summing the total annual allowable waste load permissible for each year, provides the annual waste assimilation capacity of the river, taking full advantage of the complete range of runoff experienced.

Fig. 8 shows the tabulations of the annual waste assimilation capacities thus determined for each year 1944 through 1956, maintaining under all conditions 4 parts per million of dissolved oxygen in the critical reach of the river. It will be noted that the annual waste assimilation capacity ranges from 15.6 million pounds of 5-day BOD for the year 1954-1955 to 56.8 million pounds for the year 1951-1952. Plotting these annual waste assimilation

FIGURE 7 - RIVER 'A'



capacities on normal probability paper indicates a reasonably normal distribution, as shown on Fig. 9, with a most probable annual value represented by the mean at 36 million pounds of 5-day BOD per year, and a standard deviation of 16.2 million pounds. If this rather short record is accepted as a normal representation of what can be expected in the long run through the years, then from this distribution we can say that for 50 per cent of the years the annual waste assimilation capacity would lie between the range of 25 million pounds and 47 million pounds per year. Also, on the average in the long run, not more often than once in 10 years would the annual waste assimilation capacity be expected as low as 15.5 million pounds per year; on the other hand, on the average in the long run once in 10 years, it might be expected to be as high as 56.5 million pounds per year.

Assuming for the moment that adequate lagoon storage is available to regulate the waste discharge in accord with the runoff pattern and further assuming conservatively that a 50 per cent reduction in BOD would take place in passage through the lagoon system, these annual waste assimilation capacities can be converted to equivalent mill capacity, as illustrated in the left scale affixed to Fig. 10. A 365 day working year has been assumed with a raw waste load at 80 pounds of 5-day BOD per ton of production. Thus it will be seen that for the mean or most probable annual waste assimilation capacity of 36 million pounds of 5-day BOD per year, equivalent installed mill capacity under regulated waste discharge could be 2,460 tons per day. More conservatively, taking the minimum annual waste assimilation capacity expected on the average in the long run once in 10 years (15.5 million pounds per year) the equivalent installed mill capacity under regulated waste discharge could be at a level of 1,060 tons per day. These are in contrast with what would be permitted under the restricting drought conditions of 115 cfs. and biological

FIGURE 8 - RIVER 'A'

EXPECTED ANNUAL WASTE ASSIMILATION CAPACITY MAINTAINING 4ppm D.O. IN CRITICAL REACH

BASED ON OBSERVED MONTHLY AVERAGE RUNOFF NOV. 1944 - OCT. 1956

YEAR	12 MONTH LAGOON DISCHARGE NOV-OCT MILLION POUNDS 5-DAY BOD
1944-1945	38.7
45- 46	53.0
46- 47	24.5
47- 48	51.7
48- 49	51.2
1949-1950	24.4
50- 51	19.9
51- 52	56.8
52- 53	31.2
53- 54	26.0
1954-1955	15.6
55- 56	31.8

FIGURE 9 - RIVER 'A'

DISTRIBUTION OF EXPECTED ANNUAL WASTE ASSIMILATION CAPACITY
MAINTAINING 4ppm D.O. IN CRITICAL REACH

BASED ON OBSERVED MONTHLY AVERAGE RUNOFF NOV. 1944-OCT. 1956

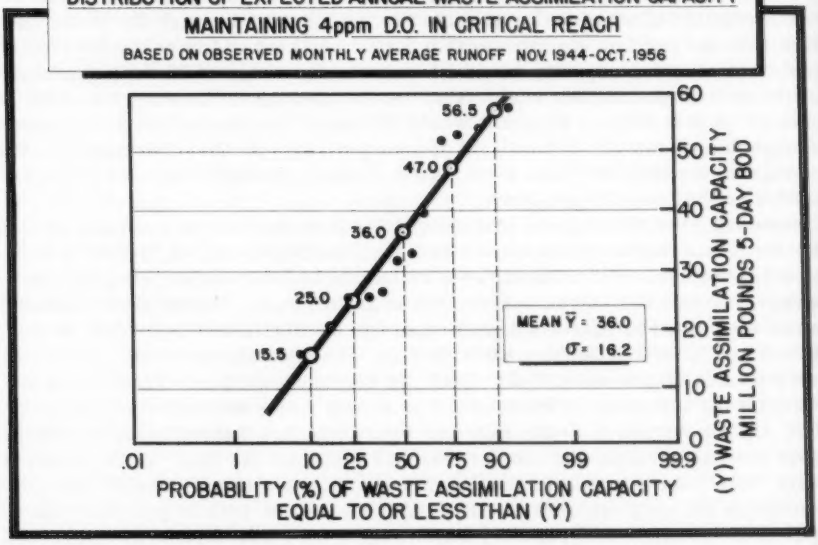
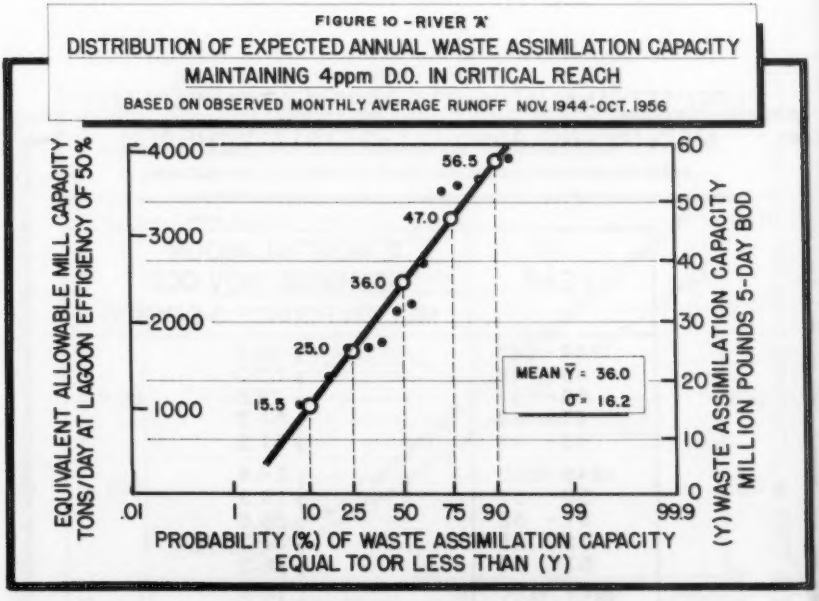


FIGURE 10 - RIVER 'A'

DISTRIBUTION OF EXPECTED ANNUAL WASTE ASSIMILATION CAPACITY
MAINTAINING 4ppm D.O. IN CRITICAL REACH

BASED ON OBSERVED MONTHLY AVERAGE RUNOFF NOV. 1944-OCT. 1956

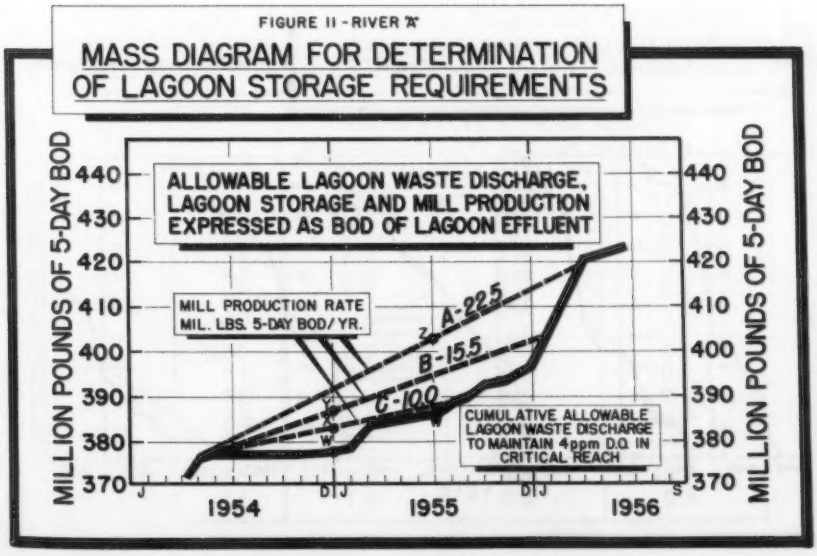


treatment of 90 per cent efficiency, which limited mill capacity to 100 tons per day. If long storage is provided through a series of well designed lagoons it is estimated by some authorities that efficiency in BOD reductions could be increased to 75 per cent. This, in turn, would double the possible installed mill capacity over that for the 50 per cent efficiency system assumed here. Thus, if the total annual waste assimilation capacity of the stream could be utilized it would provide a mill production potential 10 to 50 times that possible under restricting drought conditions.

Lagoon Storage Requirements

There remains, however, one important practical consideration, namely, the required size of lagoons in relation to the mill production capacity within the framework of the total annual waste assimilation capacity available. Since waste storage requirement is a function of inflow to and outflow from the lagoons, the principles of the mass diagram were adapted for the determination of lagoon capacity. Commencing with November, 1944, and extending through September, 1956, the mass diagrams of cumulative allowable lagoon waste effluent to maintain 4 ppm. and 3 ppm. of D.O. in the critical reach of the river were plotted. The application of the mass diagram principle is illustrated in Fig. 11, representing a section of the entire mass diagram to maintain 4 ppm of D.O., for the most critical period of record, 1954 through 1956. The maximum ordinate between the mass curve and a mill production rate curve drawn tangential to the mass curve each year provides a series of expected annual lagoon storage requirements. The irregular solid line represents the cumulative allowable lagoon waste effluent discharge and Curves A, B, and C, the continuous mill production rates of 22.5 million pounds of 5-day BOD per year, 15.5 million pounds, and 10 million pounds, respectively.

FIGURE 11 - RIVER "X"



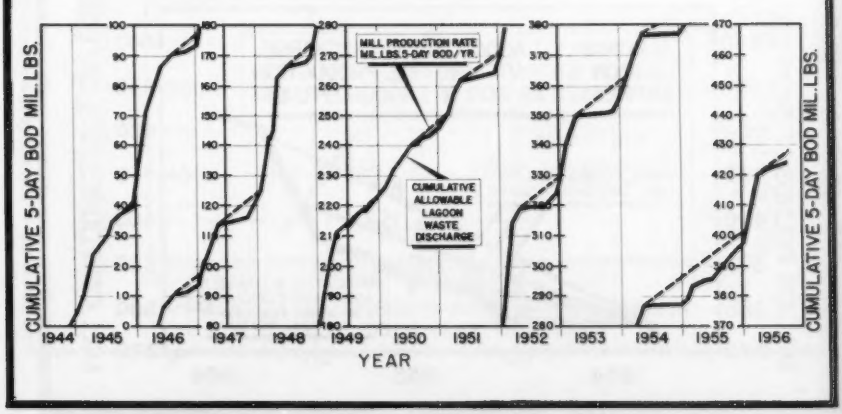
Referring to Fig. 11, the protracted low runoff and consequent low waste assimilation capacity period commencing in June, 1954, extended through February, 1955, and was followed by unusually low spring runoff. The low runoff period of 1955, however, was short, and the fall and winter experienced unusually high stream flow. It will be noted that for the mill production rate of 10 million pounds of 5-day BOD per year (Curve C) the maximum waste storage required to carry through the 1954 dry season period, given by the ordinate WX, is 5.3 million pounds of 5-day BOD, and by the spring of 1955 the lagoon would be practically empty. However, for mill production rates greater than 10 million pounds per year, the lagoon could not be emptied until the spring of 1956, requiring a carry over of waste storage from 1954 into 1956. The maximum lagoon storage required for the mill production rate of 15.5 million pounds per year (Curve B) would have occurred at the end of 1954, indicated by the ordinate WY, at 8.9 million pounds of 5-day BOD. With increase in mill production rate such as Curve A, the maximum ordinate shifts to mid-1955, with lagoon storage, indicated by WZ, at 16.5 million pounds of 5-day BOD. This represents the worst or most critical period of the entire record.

Fig. 12 shows the entire mass diagram for the period 1944 through 1956, and it will be observed that in many years little or no storage is required. Selecting the maximum ordinate each year for each of the three mill production rates gives the amount of storage which would have been required each year for these production rates under the actual runoff patterns experienced. These are listed in Fig. 13. For the mill production rate of 10 million pounds of 5-day BOD per year, lagoon storage requirements each year ranged from a minimum of 0.0 for 1945 to a maximum of 5.3 million pounds of 5-day BOD for the critical period 1954, and, of course, as would be expected, as the mill production rate is increased the storage requirements increase, as tabulated in the last two columns.

FIGURE 12 - RIVER X

MASS DIAGRAM FOR DETERMINATION OF LAGOON STORAGE REQUIREMENTS

NOV. 1944 - SEPT. 1956


CUMULATIVE 5-DAY BOD MIL. LBS.
MILL PRODUCTION RATE MIL. LBS. 5-DAY BOD / YR.
CUMULATIVE ALLOWABLE LAGOON WASTE DISCHARGE
CUMULATIVE 5-DAY BOD MIL. LBS.
1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956
YEAR

Plottings of these annual lagoon storage requirements on normal probability paper for each of the three mill production rates indicate remarkably normal distributions, making it possible to determine the probability of a storage requirement for a particular mill production rate. Finally, from these three distribution plots a set of control curves was developed (Fig. 14) giving the expected range in lagoon waste storage required for any annual mill production rate. The inner band about the most probable central curve defines the range expected in storage requirement for 50 per year of the years; the outer curves define the range expected in storage requirement for 80 per cent of the years. For example, for a mill production rate of 15.5 million pounds of 5-day BOD per year the most probable storage required would be 4.6 million pounds of 5-day BOD; for 50 per cent of the years the range in storage requirement would fall between 2.1 and 7.1 million pounds; 10 times in 100 years or once in 10 years, as indicated by the uppermost curve, at least 9.3 million pounds would be needed; but also 10 times in 100 years, as indicated by the lowermost curve, no storage would be needed. Thus, the control curves of Fig. 14 provide a probability basis for relating mill capacity and lagoon storage requirements to insure regulation of lagoon effluent discharge in accord with variation in stream runoff and resulting waste assimilation capacity maintaining at all times the prescribed 4 ppm. of dissolved oxygen in the critical reach of the river.

It will be noted that to permit this system of analysis to be more generally applicable, a common basis of measurement has been adopted; lagoon storage, the allowable lagoon waste discharge, and mill production are all expressed as BOD of lagoon effluent. Appropriate conversions to tonnage of mill production or to volume of waste can be made for specific individual situations, depending upon lagoon efficiency assumed and the strength and volume of raw waste production. A further consideration affecting lagoon capacity is the net

FIGURE 13 - RIVER 'A'

ANNUAL LAGOON WASTE STORAGE REQUIREMENTS FOR REGULATION OF EFFLUENT DISCHARGE TO MAINTAIN CRITICAL D.O. OF 4 ppm IN RIVER 'A'

BASED ON MASS DIAGRAM OF MONTHLY WASTE ASSIMILATION CAPACITY NOV. 1944 - OCT. 1956

YEAR	LAGOON WASTE STORAGE REQUIRED MILLION LBS. 5-DAY BOD FOR ANNUAL MILL PRODUCTION RATES IN MILLION LBS. 5-DAY BOD		
	10.0	15.5	22.5
1945	0.0	0.9	2.1
46	1.0	2.8	5.7
47	2.6	5.4	9.0
48	1.9	3.8	6.5
49	0.5	1.0	3.8
1950	0.3	1.6	4.9
51	3.2	6.3	10.2
52	3.1	5.5	8.7
53	4.3	7.5	12.3
54	5.3	8.9	14.0
1955	2.3	8.6	16.5
56	1.8	3.6	8.5

balance between rainfall, evaporation and seepage, which will vary with geographical location and hydrologic conditions of the particular area.

CONCLUSIONS

Given the proper setting for construction of waste storage lagoons, this case history illustrates the tremendous potential inherent in more efficient utilization of water resources through the principle of regulated waste effluent discharge. Where land areas are available, the approach outlined offers a particularly attractive possibility for a satisfactory and economical method of industrial waste disposal.

The industrial-urban giant is a thirsty giant whose increasing and varied demands upon water resources no longer can be met on a piecemeal basis of inefficient use. In the future, water resource development will extend beyond hydro power, navigation and flood control to community and industrial needs, including the key problem of waste disposal. We are upon the threshold of an era of integrated water resource development and management, looking toward utilization of a greater proportion of the total annual flow. Inevitably, then, more attention will be given to stream flow regulation to assure a higher sustained flow by ironing out the wide gap between flood and drought, or to the alternative of regulated waste discharge, tailored to the pattern of variation in stream flow.

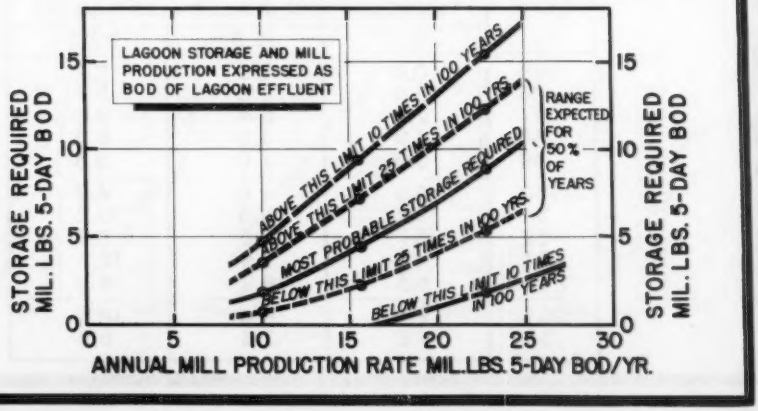
ACKNOWLEDGMENT

These studies were carried out under sponsorship of National Council for Stream Improvement, as part of the stream analysis research conducted at the School of Public Health, University of Michigan. To the staff of National

FIGURE 14 - RIVER 'A'

RELATION BETWEEN LAGOON WASTE STORAGE REQUIRED AND ANNUAL MILL PRODUCTION RATE

UNDER REGULATED LAGOON WASTE EFFLUENT DISCHARGE CORRELATED WITH RIVER 'A' RUNOFF TO MAINTAIN 4ppm OF BOD IN CRITICAL REACH


LAGOON STORAGE AND MILL PRODUCTION EXPRESSED AS BOD OF LAGOON EFFLUENT
ABOVE THIS LIMIT 10 TIMES IN 100 YEARS
ABOVE THIS LIMIT 25 TIMES IN 100 YRS.
MOST PROBABLE STORAGE REQUIRED
BELOW THIS LIMIT 25 TIMES IN 100 YRS.
BELOW THIS LIMIT 10 TIMES IN 100 YEARS
RANGE EXPECTED FOR 50% OF YEARS
STORAGE REQUIRED MIL. LBS. 5-DAY BOD
STORAGE REQUIRED MIL. LBS. 5-DAY BOD
0
5
10
15
20
25
30
ANNUAL MILL PRODUCTION RATE MIL. LBS. 5-DAY BOD/YR.

Council and to the management of their member mill involved, acknowledgment is made for cooperation in supplying field data and contribution of many of the concept basic to these researches.

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Proceedings of the American Society of Civil Engineers

WASTE WATER ROLE IN MEETING WATER REQUIREMENTS[a]

Max Bookman,[1] M. ASCE

SYNOPSIS

The water-deficient area in the southern portion of California faces the imminent need to supplement, by large quantities, the existing local and imported sources of water supply. This requires that consideration be given to the possibility of extending the use of existing sources of water by the reclamation of waste waters which would otherwise be discharged to the ocean. Presented herein is an evaluation of waste water reclamation and the relationship of the accomplishment of such projects to the forecast demands for new sources of water supply. The evaluation of the potential of waste water reclamation is based on the availability of quantities of waste waters of suitable quality which may be reclaimed at costs competitive with alternative sources of supplemental water. The markets for use of reclaimed water considered herein include direct uses for industry, agriculture, and recreation, and the indirect use through recharging the ground water supplies.

INTRODUCTION

Even though the limited and costly water supplies in the southern part of California are carefully conserved and used, and even though some waste waters now disposed of at inland points are being reclaimed for direct re-use or for ground water recharge, an increasing large quantity of wastes is being discharged to the ocean. One may wonder what has led the people to make large expenditures for facilities to discharge waste waters to the ocean, since suggestions are now being made to divert and reclaim waste waters for further beneficial use.

Note: Discussion open until April 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2255 is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. SA 6, November, 1959.

a. Presented at the February 1959 ASCE Convention in Los Angeles, Calif.

1. Dist. Engr., Calif. Dept. of Water Resources, Los Angeles, Calif.

Probably the most important influence which has led to ocean disposal of wastes is the matter of costs. Since there are no large flowing rivers in the southern part of California, the ocean becomes the natural recipient of gravity-conveyed waste waters. The ocean waters offer a high degree of dilution so that the treatment necessary prior to disposal can be decreased over that which would be required for land disposal. Furthermore, as areas urbanize there is created a climate favorable to industrial development. Many of these industrial plants create wastes which are so highly mineralized that if these wastes were disposed at inland points there could result pollution of the ground water supplies. The answer to this problem requires that such wastes be discharged to the ocean. Therefore, in coastal waters such waste of waters may be expected to continue. The disposal of such wastes, however, serves a beneficial purpose in removal of salts needed to maintain a favorable salt balance in the ground water basins.

Once such sewerage systems are constructed, however, there is an inclination to include in such ocean disposals domestic wastes primarily on the basis of lower costs for disposal, and secondarily because there are certain urban areas where land disposal is not feasible. Thus the ocean discharges of sewage have been increasing with the growth of population and may be expected to continue to increase with future growth.

The reason there is more and more interest being given to the possibilities of reclamation of water from these waste discharges to the ocean, is the increasing need for large quantities of supplemental supplies in the immediate future. Present plans for importation of supplemental water from the northern part of the State will necessarily cost more than existing supplies, and therefore consideration should be given to the possibilities offered by the reclamation of waste waters.

The coastal area of southern California from Ventura County southward to the Mexican boundary is called the South Coastal Area. This portion of California comprises some 10,900 square miles, or only seven per cent of the State's area, and yet it is one of the most highly developed regions of the State. About 55 per cent of the State's population resides in this area, the total number at present exceeding the 8,000,000 figure. The South Coastal Area is shown on Fig. 1 as well as major sewage discharges to ocean and tidal waters. Major sewage discharges to ocean and tidal waters in the South Coastal Area were studied. Separate discharges of industrial wastes to the ocean have not been considered in these studies. Generally, these discharges are either small or highly mineralized.

In the coastal areas in southern California there exist a number of sewerage systems which discharge to the ocean or to tidal waters. In the Los Angeles Region in Ventura County there are discharges at Ventura, Port Hueneme, Oxnard, and the naval installations at Port Hueneme and Point Mugu. In Los Angeles County, the major dischargers are the City of Los Angeles at Hyperion and Terminal Island, and the County Sanitation Districts of Los Angeles County at Whites Point. The principal discharge in the Santa Ana Region is the County Sanitation Districts of Orange County at the mouth of the Santa Ana River. Other minor dischargers in Orange County include the City of Seal Beach, the Sunset Beach Sanitary District, and naval installations at Seal Beach and Los Alamitos.

In the Orange County portion of San Diego Region, the main dischargers are the Cities of Laguna Beach and San Clemente, with three small dischargers at Capistrano Beach. In San Diego County, the largest discharger is the

City of San Diego. Other discharges shown are at Camp Pendleton, Oceanside, Carlsbad, Solano Beach, Del Mar, Coronado, Chula Vista, Imperial Beach, and the International Outfall Sewer near the mouth of the Tia Juana River.

In 1958, the City of Oceanside eliminated their ocean outfall and now pump their entire flow into San Luis Rey Valley for reclamation.

The dilution capacity of the tidal waters in southern California is extensively utilized by coastal municipalities for disposal of domestic and industrial waste. Once these wastes have been discharged to tidal waters they are no longer economically susceptible of reclamation.

The total quantity of waste discharges to tidal waters that may be available for reclamation in the South Coastal Area is shown in Table 1. These data are average values for the Fiscal Year 1956-57.

It should be noted from Table 1 that the total annual quantity of sewage discharged to tidal waters during the Fiscal Year 1956-57 in the South Coastal Area amounted to 549,000,000 gallons per day or 615,000 acre-feet. It should also be noted that about 454,000,000 gallons per day, or 508,300 acre-feet per year or 83 per cent of the total, was discharged in Los Angeles County.

Los Angeles Metropolitan Area

Since the major portion of the sewage presently being discharged to the ocean originates in the Los Angeles Metropolitan Area, which includes the coastal portions of Los Angeles and Orange Counties, a detailed investigation was undertaken by the State of California's Department of Water Resources

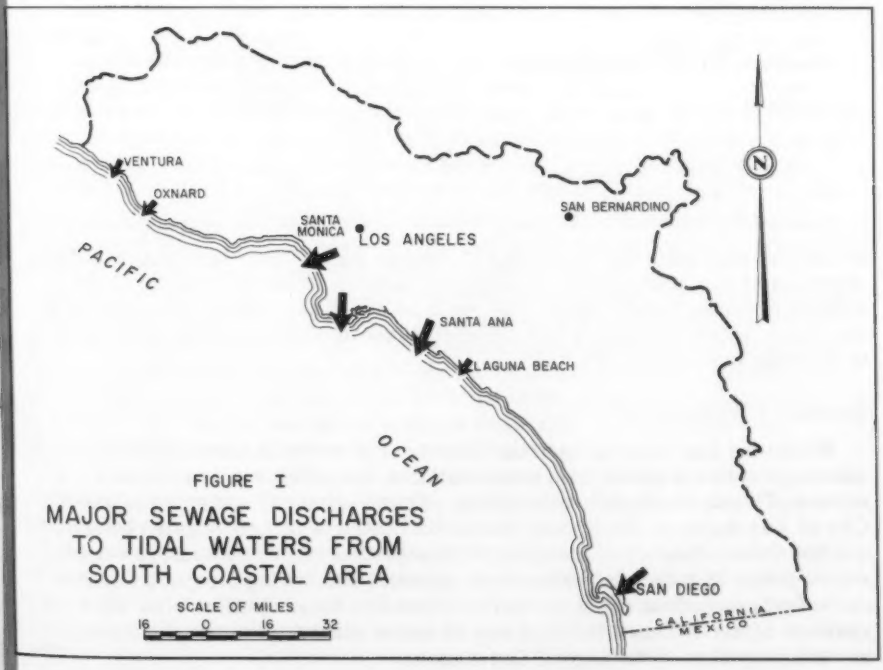


FIGURE I
MAJOR SEWAGE DISCHARGES TO TIDAL WATERS FROM SOUTH COASTAL AREA

TABLE 1

QUANTITY OF SEWAGE DISCHARGED TO TIDAL WATERS
SOUTH COASTAL AREA

Fiscal Year 1956-57

Area or agency	Million gallons per day	Acre-feet per year
Ventura County, Total	7.4	8,300
Los Angeles County		
City of Los Angeles, Hyperion	256.3	287,000
Los Angeles County Sanitation District, Whites Point	191.5	214,500
Remainder of Los Angeles County	6.0	6,800
Total	453.8	508,300
Orange County		
Orange County Sanitation Districts	34.1	38,200
Remainder of Orange County	1.8	2,000
Total	35.9	40,200
San Diego County		
City of San Diego	42.5	47,600
Remainder of San Diego County	9.6	10,600
Total	52.1	58,200
TOTAL, South Coastal Area	549.2	615,000

in 1955 to determine the feasibility of sewage reclamation in that area. The objective of this study was to evaluate the firm quantity and quality of the amount of usable water supply that could be developed that is now wasting to the ocean, and to determine comparative costs of such water in relationship to possible markets for its use.

Sources of Waste Water

Within the Los Angeles Metropolitan Area there exist three principal sewerage systems which have ocean outfalls, and which may serve as a source of waste water for reclamation. These principal systems include the City of Los Angeles, the County Sanitation Districts of Los Angeles County, and the County Sanitation Districts of Orange County. In general, the trunk sewer lines, 18 inches in diameter or greater, and having a capacity of five cubic feet per second or more, were included in these studies. The sewerage systems of the Cities of Burbank and Glendale discharge to the Hyperion sewerage system of the City of Los Angeles.

Quality of Waste Waters

The quality of waste waters originating in an area is particularly influenced by the quality of water supplied to the sewered areas. The average total dissolved solids content of the water supplied to the sewered portion of the Los Angeles Metropolitan Area in 1955 was determined for each of the three principal sewerage agencies. The total dissolved solids content of the water supplied to the area was classified into four groups: Those waters less than 300 parts per million, 301 to 500 parts per million, 501 to 750 parts per million, and more than 750 parts per million.

The quality of water supplied to the area served by the Hyperion system of the City of Los Angeles is less than 500 parts per million total dissolved solids. This accounts for the fact that the resultant sewage flow from the City of Los Angeles sewerage system is of lower mineral content than the other two systems.

Data in connection with the quantity and quality of flows in the three principal sewered systems were a necessary prerequisite to evaluation of the feasibility of sewage reclamation. In order to secure such data, the California Department of Water Resources undertook a sampling and flow measurement program during 1955 in cooperation with the local sanitation agencies.

In the City of Los Angeles sewerage system, grab samples were collected and flow measurements made at 13 sampling stations for a period of one week. There were 2,000 grab samples analyzed for chloride and electrical conductivity. Sampling was performed by personnel of the City of Los Angeles. Daily and weekly samples were composited in proportion to flow from the grab samples. All compositing and analyses were performed by personnel of the Department of Water Resources. A total of 117 complete analyses were made.

In the Los Angeles County Sanitation Districts' system, 19 grab samples were collected from separate sampling stations. From analyses of these samples, four sampling stations were selected. Continuous sampling devices and recorders for measuring flow were installed at each of these stations by Los Angeles County Sanitation District personnel. Daily samples were collected at each of the stations for one week. These 28 samples were given complete analysis. Weekly composite samples were also prepared and analyzed. In addition, 60 grab samples were collected for analysis for pH, chloride concentration, and electrical conductivity.

In the Orange County Sanitation Districts' system, samples were collected only at Plants 1 and 2. At Plant 1, grab samples were collected every two hours for a period of one week. These 84 samples were analyzed by Orange County Sanitation District personnel for chloride and electrical conductivity. Seven daily samples were prepared from the grab samples and given complete analysis. Continuous daily samples were also collected from both plants. These 14 samples were given a complete analysis.

In all, 2,809 grab samples and 42 continuous daily samples were collected during the program. The grab samples include those taken for B.O.D. and phenol determinations.

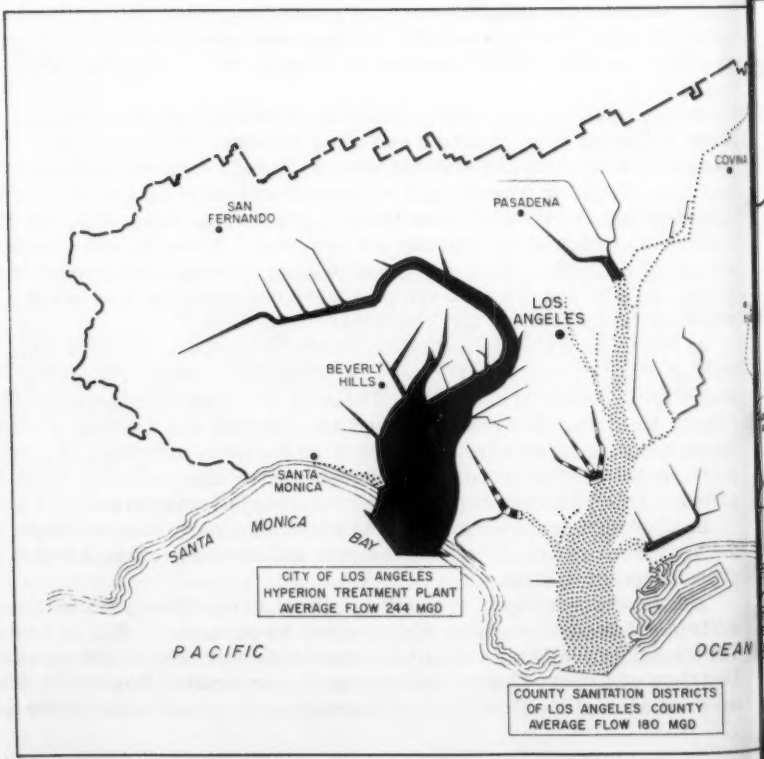
The quantity and quality of sewage flows in the three principal sewerage systems of the Los Angeles Metropolitan Area, namely, City of Los Angeles, County Sanitation Districts of Los Angeles County, and County Sanitation Districts of Orange County, are shown in a schematic diagram in Fig. 2. The width of each of the flow lines is approximately proportional to the quantity

of flow. The largest sewage discharge to the ocean, amounting to 244 million gallons per day, occurs at the Hyperion Plant of the City of Los Angeles. The discharge at the Whites Point Plant of the County Sanitation Districts of Los Angeles County amounts to 180 million gallons per day, and the discharge of the County Sanitation Districts of Orange County amounts to only 21 million gallons per day.

The mineral quality of the various sewage flows is grouped in three classifications based primarily on the total dissolved solids content, as follows: Satisfactory, less than 1,000 parts per million total dissolved solids; marginal, 1,000 to 2,000 parts per million total dissolved solids; and unsatisfactory, more than 2,000 parts per million total dissolved solids.

A comparison of mineral quality of water supplies and sewage discharge is shown on Fig. 3, which compares the total dissolved solids, total hardness as calcium carbonate, and chloride concentrations. Representative ground waters from the interior basins of San Fernando and San Gabriel Valleys, and the coastal basins of Los Angeles and Orange Counties are shown based on analyses of samples collected during Fiscal Year 1955-56. The quality of the presently imported Mono-Owens and Colorado River (both raw and softened) supplies, and the quality of the proposed San Joaquin-southern California aqueduct are shown based on average values for Fiscal Year 1955-56.

The quality of several typical sewage flows is also shown on Fig. 3 to permit a comparison to be made with the quality of water supplies. The quality



of sewage flows at three potential diversion points for reclamation is shown, including the San Fernando Valley trunk at Mission Road, the Hyperion Plant effluent, and the San Gabriel Valley trunk at Whittier Narrows. These values are from analyses of composite samples collected over a period of one week during the period June to December, 1955. Fig. 3 also shows the quality of the effluent from the Los Angeles County Sanitation Districts' Joint Disposal Plant (discharging at Whites Point) in November, 1955. This poor quality, which is attributable to the saline industrial waste discharges to the system, illustrates the significance of mineral quality in the reclamation of water from wastes.

Finally, Fig. 3 shows the quality of the effluent from Plant No. 1 of the Orange County Sanitation Districts during March, 1955. At the time this sample was collected, most of the industrial wastes were diverted to Plant No. 2. This same arrangement has been followed as closely as possible in order to enable effluent from Plant No. 1 to be used for surface irrigation of crops by the Talbert Water District.

Problems Affecting Feasibility

The successful and worthwhile reclamation of water from wastes will require adequate quantities of sewage of satisfactory quality. Because of large fluctuations in flow, storage reservoirs with capacity for one day's flow would

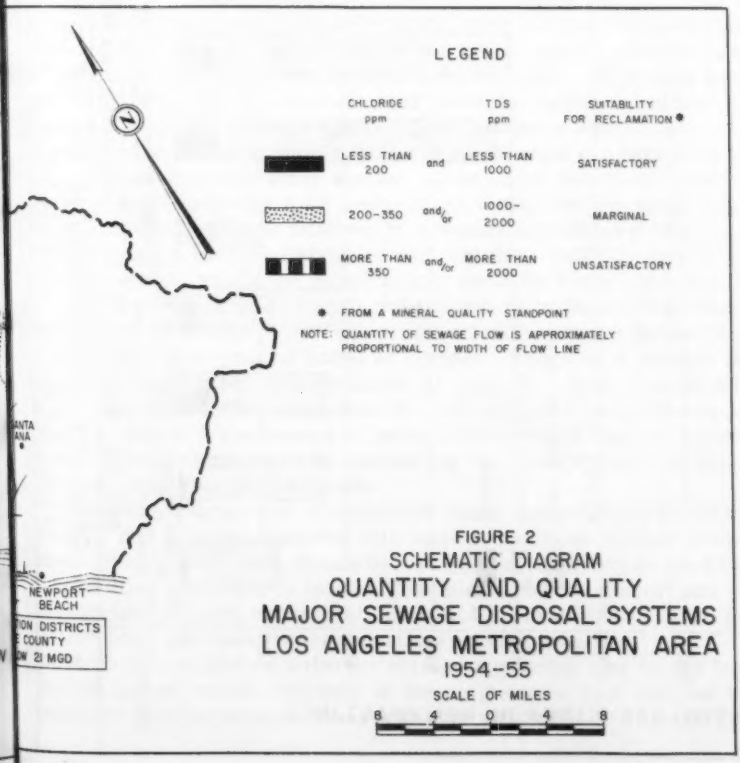

LEGEND
CHLORIDE ppm
TDS ppm
SUITABILITY FOR RECLAMATION *
LESS THAN 200 and LESS THAN 1000 SATISFACTORY
200-350 and/or 1000-2000 MARGINAL
MORE THAN 350 and/or MORE THAN 2000 UNSATISFACTORY
* FROM A MINERAL QUALITY STANDPOINT
NOTE: QUANTITY OF SEWAGE FLOW IS APPROXIMATELY PROPORTIONAL TO WIDTH OF FLOW LINE
NEWPORT BEACH
8 4 0 4 8

FIGURE 2
SCHEMATIC DIAGRAM
QUANTITY AND QUALITY
MAJOR SEWAGE DISPOSAL SYSTEMS
LOS ANGELES METROPOLITAN AREA
1954-55
SCALE OF MILES

FIGURE 3
QUALITY COMPARISON OF SELECTED WATER SUPPLIES
AND SEWAGE DISCHARGES IN SOUTHERN CALIFORNIA
CONCENTRATION IN PARTS PER MILLION
2600
2400
2200
1000
800
600
400
200
0
2,550
LEGEND
TOTAL DISSOLVED SOLIDS
TOTAL HARDNESS AS $CaCO_3$
CHLORIDE
SOURCE
GROUND WATER
IMPORTED WATER
SEWAGE
INTERIOR BASINS
COASTAL BASINS
SAN FERNANDO VALLEY
SAN GABRIEL VALLEY
LOS ANGELES COUNTY
ORANGE COUNTY
MONO-OWENS AQUEDUCT
COLORADO RIVER AQUEDUCT
RAW
TREATED
PROPOSED SAN JOAQUIN VALLEY AQUEDUCT
SAN FERNANDO VALLEY TRUNK AT MISSION ROAD
SAN GABRIEL VALLEY TRUNK AT KLINGERMAN ST
HYPERION EFFLUENT
WHITES POINT EFFLUENT
ORANGE CO PLANT NO 1 EFFLUENT

be needed at reclamation plants. The reclamation agency should be protected by a firm contract for the supply of sewage discharged by another agency. The mineral quality of sewage can be adversely affected by discharges of toxic, aromatic, or highly saline industrial wastes. Sewerage agencies, however, now have the right to exclude discharges to their systems which are a hazard to health or structures, or which may interfere with treatment processes. Such control should be exercised to protect the mineral quality of the supply to the reclamation plant since demineralization of these waste waters is not economically feasible.

Well developed and time tested sewage treatment processes can be utilized in the water reclamation plant, and no major problems are anticipated in a well designed plant. In the water reclamation plant, the avoidance of odors and nuisance will be particularly important. Maintenance and operation of the plant must be carefully performed to assure public acceptance of the concept of reclamation.

One of the problems which has been experienced in the operation of reclamation plants is caused by the increased use of synthetic detergents. These synthetic detergents may affect the type of treatment necessary, and may result in nuisance from foaming of the reclaimed water, particularly at aeration tanks. Methods of controlling this at various plants have included water sprays or defoaming agents. Further developments are needed to cope with this problem, and information is needed on the toxicity of synthetic detergents as well as the travel of synthetic detergents in ground water basins.

Other problems concern the protection of public health. This would require approval of local and state health authorities and the regional pollution control boards. General indications of the requirements of these agencies for the protection of public health have been set forth. There are certain requirements for the use of reclaimed water for agricultural use, certain industrial uses, and surface spreading for ground water recharge. Except on an experimental basis, to date reclaimed sewage has not been injected into wells to recharge a ground water aquifer. It has been indicated, however, that minimum requirements for such applications would include sand filtration of a highly oxidized effluent followed by adequate disinfection and chemical oxidation to meet bacterial standards for drinking water provided that injection wells are separated from water supply wells by a sufficient distance to allow enough time for dilution by the natural waters in the ground water basins. One of the problems requiring careful attention from a public health standpoint is the underground travel of viruses. There is at present no information available on the underground travel of viruses. From a public health standpoint, standard techniques available to water plant laboratories are not adequate to detect the presence of some viruses which may be present. Development of better techniques in monitoring the reclaimed water will be needed from a public health standpoint.

Direct industrial use of reclaimed water appears to hold considerable potential, and it is believed that this market should be further studied and evaluated. Reclaimed water should be suitable for many rough washing, quenching, and similar applications in steel, chemical, power, rubber, and petroleum industries. Quality considerations would preclude textile, food processing, boiler feed, and many other industrial applications.

Recharge of ground water by surface spreading may be the largest market for reclaimed water. Not only is the reclamation cost low, but there are years of successful experience with this application. For any large scale

reclamation project, planning must consider the hydrologic aspects of infiltration rates, transmissibility, pumping pattern, head differential, distance between area of recharge and area of use, and underground storage capacity. Respecting this latter factor, consideration must be given to the fact that in actual operation of facilities and storage capacity, first priority should be given to the conservation of local runoff which will generally be of much better mineral quality.

Plans for Reclamation

In developing a plan for use of reclaimed water in the Los Angeles Metropolitan Area, it was found that major water users are particularly interested in a consistent quality and reliability of supply. They are also interested in the cost of water and the possible cost of additional plant facilities such as dual pipe distribution lines and storage capacity which may be required. The industrial user is concerned with the quality and the physical characteristics of reclaimed water which would increase his treatment and maintenance cost.

When economics of required distribution systems are considered, potential, large-scale, industrial markets were found to be limited to the four industrial areas of Vernon, Torrance, Wilmington, and El Segundo.

The recharging of ground water basins by spreading or injection is the most promising market for reclaimed water. This indirect use of reclaimed water would serve all prevailing beneficial uses which secure water by pumping from the ground water basins.

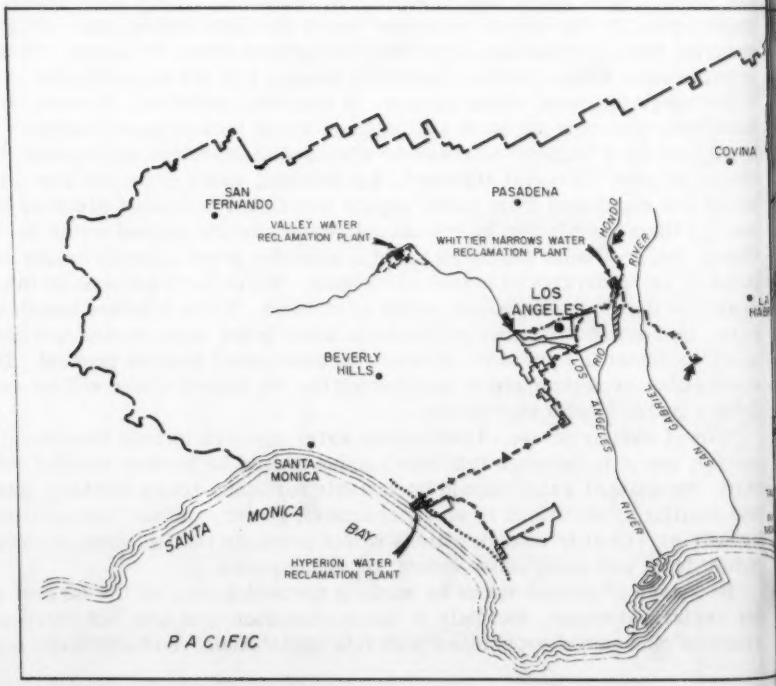


Fig. 4 shows the diversion points, reclamation plants, principal distribution lines, and areas of use for a possible reclamation system in the Los Angeles Metropolitan Area. The principal suggested reclamation plants are located at Hyperion and at Whittier Narrows. Upon completion of a new five-mile outfall, the City of Los Angeles plans to convert the Hyperion Sewage Treatment Plant to primary treatment. When this occurs, it will be possible to convert a portion of the existing plant to provide secondary treatment to 125 million gallons per day. The water reclaimed could be pumped to industrial areas at Vernon, El Segundo, and Torrance for industrial purposes, and to spreading grounds near Torrance. With a polishing treatment added, water could be utilized for repressuring the sea-water intruded, deep aquifers of West Coast Basin by means of injection wells.

The Whittier Narrows reclamation plant could treat sewage diverted from the City of Los Angeles outfall sewer, and from the Los Angeles County Sanitation Districts' Joint Outfall B. Studies were made of diverting flows from the South Whittier trunk of the County Sanitation Districts of Los Angeles County to the same reclamation plant, but excessive conveyance costs would probably preclude this diversion. Effluent from the reclamation plant would be principally available for spreading in the Montebello Forebay Area to recharge the ground water supplies.

An additional possible reclamation plant could be located at the Valley Settling Basin. Effluent from this plant could be used for irrigation in Griffith Park. The excessive cost of treating such a small flow makes this a less desirable reclamation project, at least at the present time.

FIGURE 4

WATER RECLAMATION PLAN
LOS ANGELES METROPOLITAN AREA

There is at present a reclamation project in operation. By means of pumps, the Talbert Water District diverts a portion of the effluent from the Orange County Sanitation Districts' Plant No. 1 to a regulation reservoir. The reclaimed water is distributed to the adjacent farm lands for pre-irrigation of beans and selected crops. Because of the possibility that slugs of saline water may be discharged from the treatment plant, a precautionary device has been installed. An electrical conductivity bridge circuit has been installed in the pump circuit which automatically stops the diversion of effluent when the electrical conductivity of the effluent reaches a certain value.

In the over-all reclamation program that has been outlined, it should be noted that there is essentially no continuous recycling of the water. Water diverted and reclaimed from the sewerage systems will be conveyed to areas served by the County Sanitation Districts of Los Angeles County with final disposal to the ocean via the Whites Point Outfall.

The yields, markets, and unit costs of potential water reclamation projects in the Los Angeles Metropolitan Area are shown in Table 2. These costs reflect the capital costs for diversion, reclamation plant, and delivery of the reclaimed water to the point of use, and annual operation and maintenance charges.

TABLE 2

POTENTIAL WATER RECLAMATION PROJECTS
IN LOS ANGELES METROPOLITAN AREA

Reclamation plant and project	Market	Yield in acre-feet per year	Unit cost in dollars per acre-foot
Hyperion Plant			
Vernon	Industrial	45,000	$19.00 - $23.00
Torrance	Industrial and Spreading	41,000	12.50 - 15.00
West Coast Basin	Recharge by Injection	54,000	14.50 - 17.50
Whittier Narrows Plant			
San Fernando and San Gabriel Valleys	Recharge by spreading	72,000	15.50 - 18.50
South Whittier	Recharge by spreading	4,400	27.00 - 33.00
Griffith Park Plant	Irrigation	3,000	31.50 - 38.50
Orange County Sanitation Districts Plant			
Talbert Water District	Irrigation	2,800	5.85 - 7.85

The accomplishments of the principal projects, including the Hyperion and Whittier Narrows Plants, should be noted. A Hyperion Waste Water Reclamation Plant could produce about 140,000 acre-feet a year for industrial use

in Vernon and Torrance and for spreading the injection along the coast, to abate sea-water intrusion, at unit costs ranging from $12.50 to $23 per acre-foot.

A waste water reclamation plant at Whittier Narrows, utilizing sewage from San Fernando and San Gabriel Valleys, could produce 72,000 acre-feet per year for recharging the coastal plain ground water basin at unit costs ranging from $15.50 to $18.50 per acre-foot.

At present and probably for the next 11 years, alternate water supplies from the Colorado River are available for ground water replenishment at incremental costs of $12 per acre-foot, which indicates that these potential waste water reclamation projects are not yet competitive with other sources of supply.

San Diego Metropolitan Area

In this area, the principal discharge of sewage is from the City of San Diego system. In general, the mineral quality of sewage in the San Diego Metropolitan Area is poorer than that of the Los Angeles Metropolitan Area, and the effluent from the City of San Diego sewage treatment plant is unsuitable for reclamation. Studies indicate that if water is to be reclaimed for beneficial purposes, reclamation must be accomplished by diversion from principal trunk sewers for park irrigation and ground water recharge. Ground water recharge possibilities are very limited. Preliminary estimates indicate that less than 25 per cent of the sewage discharge to tidal waters in the San Diego Metropolitan Area would be reclaimable for beneficial purposes. Although no cost estimates have been made, the excessive distances between the sewage sources and large potential markets and large differences in elevation detract from the possibility of economical reclamation of water from sewage on a large scale.

Future Role in Southern California

Having evaluated the possibilities of waste water reclamation, this source of supply may be viewed with respect to water requirements. Such a comparison is shown in Table 3 for the South Coastal Area for 1955.

It is significant to note that of the total water requirement of 1,841 million gallons per day, the water supply potentially reclaimable from sewage, which is now discharged to the ocean, is 205 million gallons per day, or 11 per cent. The estimate of 230,000 acre-feet per year of potentially reclaimable sewage includes: (1) Los Angeles Metropolitan Area, 215,000 acre-feet; (2) San Juan Capistrano, 480 acre-feet; (3) City of Oceanside, 1,530 acre-feet; (4) City of San Diego, 12,600 acre-feet.

Although a ground water overdraft of 333,000 acre-feet per year is shown as of 1955, the balance of the entitlement to the Colorado River supply was 826,000 acre-feet which could have been used to eliminate the overdraft. Since the potential waste water reclamation projects set forth are not competitive with the incremental cost of Colorado River water, the incentive at this time for reclamation does not exist.

The future situation is, however, quite different. Recent studies completed by the California Department of Water Resources find that tremendous urban development may be expected in the South Coastal Area in the next 60 years.

TABLE 3

WATER REQUIREMENTS AND SOURCES OF SUPPLY
SOUTH COASTAL AREA

1955

Item	Million gallons per day	Thousands of acre-feet per year
Water requirements		
Urban-suburban	1,074	1,203
Agricultural	767	859
Total	1,841	2,062
Water supply		
Safe yield of local supplies	929	1,041
Ground water overdraft	297	333
Imported supplies:		
Los Angeles Aqueduct	270	302
Colorado River Aqueduct:*		
Imported in 1955	345	386
Balance of entitlement	737	826
Sewage discharges to tidal waters	512	574
Water supply potentially reclaimable from sewage**	205	230

* Total entitlement from Colorado River equals 1,212,000 acre-feet per year.

** Assuming available markets for reclaimed water.

By 1970, only 11 years away, it is anticipated that the total water requirement of the South Coastal Area will be 2,957,000 acre-feet per year, or 2,640 million gallons per day, a 43 per cent increase. In the next 25 years, water requirements are expected to double. By the year 2020, it is estimated that the water requirement will increase to 5,846,000 acre-feet per year, or 5,220 million gallons per day.

At this rate of increase, existing sources of imported supplies are expected to be utilized to full capacity by 1970.

It is apparent from the estimates of future water requirements that waste water reclamation could not meet these needs by a wide margin, so that imported fresh water from the northern portion of California will be necessary.

With increasing use of water for urban and suburban purposes, the quantities of sewage effluent will increase and the feasibility of waste water reclamation will be enhanced. It is, therefore, important to continue investigation,

research, and planning with the view towards the future accomplishment of waste water reclamation and the possible development of this source of supply to meet a portion of the supplemental water requirements.

CONCLUSIONS

As a result of the studies of waste water reclamation and the growing demands for supplemental water supplies in southern California, it is concluded that:

1. Of the present water use in the South Coastal Area of some two million acre-feet a year, about 560,000 acre-feet or 28 per cent is being discharged to the ocean as sewage, and the quantity has been steadily increasing with continuing urban growth.
2. The total quantity of sewage discharge should not be classed as "waste" since it serves a necessary beneficial purpose in disposing of saline and toxic waste products of today's urban development.
3. The mineral pickup inherent in urban and industrial use of water limits the use of reclaimed water for ground water recharge, but unfavorable salt balance conditions in ground water basins can be avoided by careful planning and operation. The plan studied limited the application of reclaimed water to coastal areas where it would be subject to only one re-use.
4. The greatest quantities of sewage available for reclamation accumulate at the coast at low elevation, requiring expensive pumping and conveyance facilities to supply potential markets inland at higher elevations.
5. Less than half of the sewage currently discharged to the ocean is of suitable mineral quality to be reclaimed for ordinary municipal purposes. The sewage classed as suitable quality for reclamation purposes may tend to increase in salt concentration in the immediate future or until such time as water from northern California is distributed to the sewered areas.
6. Before initiation of any project designed to reclaim water from sewage, there should be a definite market or use for such water, and the cost should be competitive with alternative sources of supplemental water.
7. Because of public health and aesthetic considerations, potential markets for water reclaimed from sewage in the future, when competitive in cost with other sources, will be limited to certain industrial purposes, recharge of ground water aquifers, repulsion of sea-water intrusion, and minor agricultural and recreational purposes.
8. Reclamation of waters from sewage which would otherwise be discharged to the ocean, could provide but a small increment of the total water demand, but as such may be a very important source of supply as a safety factor in event there is a delay in the introduction of northern California water, and also would help in reducing the total import requirements.

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SLUDGE DISPOSAL IN PHILADELPHIA[a]

Samuel S. Baxter,[1] F. ASCE

ABSTRACT

The paper describes the plants and problems of the sludge disposal in Philadelphia as well as the financial aspects. The paper also discusses the selection of the method finally decided to be used.

INTRODUCTION

The problem of sewage sludge disposal at Philadelphia is comparatively new. Although a small pilot plant was operated as far back as 1912, and a 60 m.g.d. Imhoff plant began operation at Northeast Works in 1923, no sludge disposal problems were apparent until post war construction began on the complete program for treatment of Philadelphia sewage.

This program has brought about the construction of three modern treatment plants. A brief description of these three plants, each serving about one-third of the City, will help in the consideration of the sludge disposal problem. Fig. 1 shows the location of treatment plants in Philadelphia.

Description of Treatment Plants

Northeast Works, on the Delaware River, started operation as a secondary treatment plant in 1951, with a capacity of 125 m.g.d. The process consists of screening and grit removal, primary settling, aeration, final sedimentation, and digestion of sludge. The plant is now operating at full capacity, and is scheduled for expansion of 36% beginning in 1962. Secondary treatment is required at the plant because of its location on tidal water in proximity to the

Note: Discussion open until April 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2266 is part of the copyrighted journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. SA 6, November, 1959.

a. Presented at October 1958 ASCE Convention in New York, N. Y.

1. Water Comm. and Chf. Engr., Water Dept., City of Philadelphia, Pa.

Philadelphia water intake at Torresdale. The plant replaces the former 60 m.g.d. Imhoff installation at this location which began operation in 1923. The plant is designed for 75% removal of suspended solids and B.O.D., although actual performance is below these amounts in recent years.

Southeast Works and Southwest Works are located further downstream on the tidal portion of the Delaware River. These primary treatment plants are similar in size and operation, except for sludge disposal. The treatment consists of screening and grit removal, pre-flocculation, primary sedimentation, and sludge digestion. Each plant has a capacity of 136 m.g.d. and each is now running at 75% capacity. Both plants are designed for easy expansion as secondary treatment plants.

PHILADELPHIA SEWAGE TREATMENT PLANTS
FIG. 1

Sludge from both these plants is digested at Southwest Works. The sludge is pumped from Southeast to Southwest Works through a 5-mile long 8" force main, which passes under the Schuylkill River on its way between the two plants.

Early planning, and the location of the plants, has had an effect on the present day sludge problem. Northeast Works was acquired in 1917 and contains 165 acres. Some of this is available and has been used for lagoons for sludge disposal.

Southwest Works was acquired in 1910, in a location where land was cheap, and where the early planners envisaged trickling filters spread over a large area. Because of this, the original Southwest Works site contained 1,028 acres. Digested sludge from this plant and from Southeast Works is lagooned at this site, and there is land available for lagooning of this sludge for the next 25 to 30 years, at present removal rates.

Southeast Works was acquired in 1925, but because of potential development of the area, and holdings for industrial and shipping use, the site was limited to 63 acres. There is no available land at this location for sludge disposal.

Serious planning for construction of the three treatment plants began in the 1930's, but except for interceptors, no real construction work started until after World War II. All of the original planning contemplated disposal of sludge in lagoons. Not much consideration was given to future sludge disposal after lagooning.

The enactment of a sewer rent in Philadelphia, beginning in 1946, gave definite promise that the long delayed construction of the three modern treatment plants could get under way. With the design work for the new construction came studies for present and future methods of sludge disposal.

Northeast Works—Sludge Disposal Studies

A study and report made in 1946 recommended the use of existing lagoons at Northeast Works for the disposal of digested sludge. Some of the sludge from the old Imhoff tanks had been placed in these lagoons, but it was estimated that additional capacity was available for about 8 years of operation. At the time of that report, incineration of sludge was considered to be the successor method, when the lagoons were filled.

There are four lagoons which have been used for disposal of sludge at Northeast Works. Some of this space was used for disposal of sludge from the early Imhoff tanks, but most of it has been used during the operation of the existing plant since 1951. The four lagoons have a total capacity of 180 million gallons and have an average depth of 10 feet. Their original capacity has been increased by building dikes in recent years.

Following the recommendations of the 1946 report, work was started in 1955 on the preparation of contract drawings and specifications for the construction of sludge incineration and related facilities at Northeast Works, and funds for the construction were made available in the capital appropriation to the Water Department for the year 1957. It was the intention that such facilities would be ready for operation in 1959, which was the time when it was estimated that the lagoons would be filled to capacity.

In the fall of 1956, developments at several places around the country led to a decision to review again the entire problem of sludge disposal before

proceeding with the construction of a $3,000,000 capital facility. One of the major developments which caused a review in Philadelphia was the change-over in the plan of operation at the new Los Angeles plant. Although a substantial investment had been made in contract drawings (the plans were 90% complete), the stakes involved were high enough to warrant halting work on further plans.

New studies were agreed upon in November 1956. It was decided that although the basic study would center on the Northeast Works, consideration would be given to sludge disposal at the other two plants, which were in operation by that time. This decision was colored by the realization that some of the alternate methods of sludge disposal at Northeast might also involve the Southeast and Southwest Plants.

Fourteen different methods, or combination of methods were considered for disposal of Northeast sludge. Of these, six were chosen for detailed analysis and consideration.

A listing of the various methods will give some idea of the many considerations which were studied:

A - Pumping sludge to Southwest via Southeast sludge pumps
B - Pumping wet sludge to Southwest Lagoons
C1 - Trucking wet sludge to Southwest Lagoons - 5% solids
C2 - Trucking wet sludge to Southwest Lagoons - 10% solids
D - Trucking sludge cake to Southwest
E1 - Barging wet sludge to sea - 5% solids
E2 - Barging wet sludge to sea - 10% solids
F - Composting
G - Modified program with incineration
H - Discharging into Delaware River at site
I - Pumping wet sludge to Southeast Collecting system
J - Pumping wet sludge to Southwest Collecting system
K - Dewatering and Incinerating sludge
L - Excavate lagoons at intervals—Truck 18% solids to Southwest

From preliminary review, projects A, F, G, I and J were eliminated as not being practicable. Projects C1 and E1 were eliminated since their respective alternates C2 and E2, seemed to be more favorable. Project D was eliminated in the preliminary review because of a high annual cost.

Before examining the various methods in detail, Table 1 shows the estimated quantity and type of sludge at Northeast Works. These quantities are estimated for the years 1965 and 1980. They are based on 8 years experience in the operation of the plant, and differ somewhat from the estimates made in 1946 before construction of the Northeast plant.

The 1946 report estimated that by 1960, the average daily quantity of dry digested solids would be 182,000 lbs. Present studies indicate that the 1965 comparable figure is 122,000 lbs.

Current studies on capacity of sludge disposal facilities have used the estimated daily average for the maximum month in 1980 as 180,000 lbs., and total annual costs based on the annual average of daily sludge in 1965 at 122,000 lbs.

There were many existing factors involved in selecting a method of sludge disposal. Some of these were:

1. The existence of complete sludge digestion facilities at Northeast and Southwest plants, with capacities sufficient for normal expansion beyond the year 1980.
2. The several limitations on the disposal of raw sludge in the metropolitan area, because of the present and future development of land areas, and the intense use of water areas for commercial and recreational purposes.
3. The absence of lagoon space at Southeast Works, and the filling of present lagoon space at Northeast Works in the very near future.
4. The existence of large areas for lagooning at Southwest Works, with capacity to dispose of sludge for approximately the next 20 years from all plants, using present methods of treatment.
5. The immediate proximity to the Southwest Works of the Philadelphia International Airport and large industrial plants, the expansion of which may make the value of land in the Southwest Works too high for use as lagoons.

For the various purposes of studying sludge disposal, the wet sludge has been considered to contain 5% solids, with possibility of thickening to 10%. When disposed of on lagoons and allowed to drain for two years, the sludge is estimated to contain 18% solids; sludge cake was considered as 25% solids.

A description is given of the various projects which were considered:

Table 1. (Northeast Works - Sludge Quantities)

Item	Year 1965	Year 1980
Population	1,100,000	1,220,000
Sewage Quantities, M.G.D.		
Annual Average	135	150
Maximum Month	155	170
Suspended Solids, P.P.M.		
Annual Average	245	245
Maximum Month	300	300
Digested Suspended Solids to be Disposed of per 24 hours		
Pounds		
Annual Average	122,000	135,000
Maximum Month	164,000	180,000
Gallons at 5.0 per cent solids		
Annual Average	292,800	324,000
Maximum Month	393,600	432,000

Project A

This project called for pumping digested sludge from Northeast to Southeast, mixing it there with undigested sludge from Southeast, and the pumping of the mixture through the present force main to Southwest. The resultant mixed sludge could have caused problems which are unanswerable at this time. The alternates of pumping the raw sludge from Northeast to Southeast, or building digestion tanks at Southeast, would have led to abandonment of valuable facilities or the construction of expensive new facilities. This project was ruled out early as impractical.

Project B

Pumping digested sludge from Northeast directly to Southwest for disposal on lagoons at that location was deemed worthy of detailed consideration. It would require the construction of a 12-1/2 mile 12" force main, much of which would go through developed sections of the City. Estimated construction cost was:

Pumping Station and Related facilities	$ 75,000
Force Mains	1,560,000
Dikes and weirs for lagoons	200,000
Misc.	107,000
Engineering, contingencies	388,000
	$2,330,000

Annual operating costs for the project were estimated as follows:

Labor	$ 9,000
Power	1,000
Maintenance, repair, supplies	24,300
Replacement of equipment	1,000
Debt Service	125,700
	$ 161,000

Involved in this project is the consideration of the use of the present vacant land at Southwest Works as lagoons, rather than for industrial development.

Projects C1 - C2

These projects contemplate hauling sludge from Northeast Works to Southwest Works, at 5% and 10% of solids respectively. C1, the 5% project, will not be described, except to note that although the initial construction cost is $886,800 compared to the corresponding cost of $1,359,000 for the C2 project, the annual operating costs are in reverse order with C1 estimated at $392,700 and C2 at $268,200.

In the C2 project, wet digested sludge is estimated to amount to the following:

Annual Average 1965	855 tons
Annual Average 1980	945 tons
Maximum Month 1980	1265 tons

In this project, digested sludge from the tanks would be pumped to an existing lagoon for thickening. The thickened sludge would be raised to an elevated storage tank, and loaded into tanks of the semi-trailer type.

The trailers would have a capacity of approximately 17 tons, or 4,000 gallons, and the one-way trip is 13 miles. It was planned that the hauling would be done at night.

Project D

In this project it was contemplated that the sludge from the digestion tanks would be elutriated and dewatered at Northeast Works, and the resultant sludge cake hauled to Southwest for disposal on open areas. This project would have required some of the facilities which are part of those described in Project K. There is also the possibility of use of some of the sludge cake as a soil conditioner, and the possibility of disposal on other areas. Despite this, the initial cost of $1,747,000 and the comparatively high annual cost caused this project to be ruled out.

Project E1 - E2

These are similar projects for hauling digested sludge to sea. See Fig. 2. Project E1 covers the hauling of 5% sludge, and E2 calls for hauling of 10% sludge.

Again, no complete reference will be made to Project E1, except to compare its estimated costs with E2. Construction costs for E1 are lower than E2, with figures of $1,038,000 and $1,379,000 respectively. Annual costs are in reverse order, with $195,500 for E2, and $262,900 for E1.

In the E2 project, sludge thickening to 10% would be done in lagoons. The sludge will be pumped from the lagoons to the barges. Alternate proposals of using trestles, draglines, and pumping stations on one hand and a small floating dredge in the lagoon on the other hand, have been considered in estimating this project.

The Northeast Sewage plant is located on the Delaware River, and an existing pier is available, so that no new pier construction will be necessary. Some preliminary dredging and some annual dredging will be required in the dock.

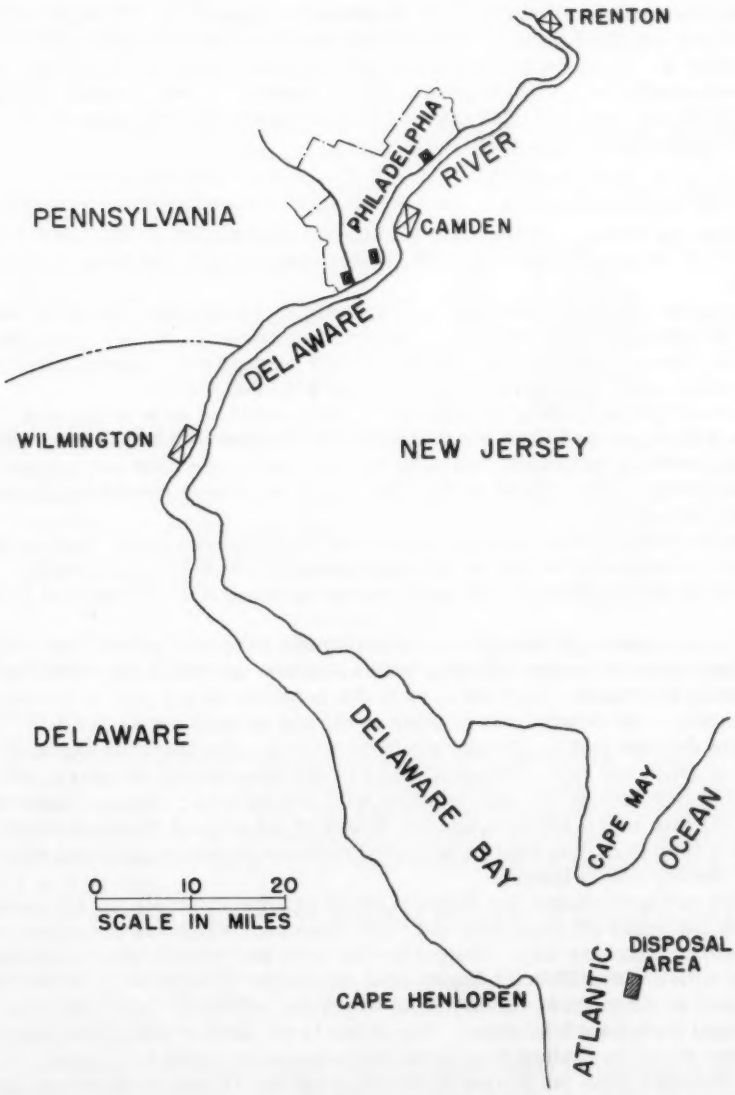
Several methods of hauling were considered. Principal points were self-propelled vs towed barges, the size of the vessels, and unloading by pumping vs. gravity discharge. Also involved in the selection of the type of vessel was the location of the dump area, whether in the bay or in the open ocean.

It was decided that no attempt would be made to discharge the digested sludge in Delaware Bay. The existence of very large areas of natural and planted oyster beds in the bay, together with fishing areas was one factor in ruling out this area. Another was the desire of the City of Philadelphia to reduce to a minimum, any real or supposed nuisance to the neighboring states of New Jersey and Delaware.

A site has been chosen for disposal which is approximately 11-1/4 nautical miles in the ocean off Cape May and Cape Henlopen, which are the capes at the mouth of Delaware Bay. The particular area was chosen after consultation with the office of the District Engineer of the Corps of Engineers, as the least likely spot in the general vicinity from which any currents would carry the discharged sludge back to shore. The ocean is 65' deep at that point, and the discharge would be limited to an area approximately 1 mile by 2 miles.

The distance from the Northeast Works down the Delaware River and Bay and into the ocean to the disposal point is 97 nautical miles.

Studies were made of comparative cost of purchasing and operating self-propelled vessels, and the use of towed barges. The cost factors were overwhelmingly in favor of the towed barges. The real studies revolved around the size of the barges, in which quantities of sludge and number of trips required were balanced against the cost of building and towing various size barges.



PROPOSED SLUDGE DISPOSAL AREA
FIG. 2

Sludge quantities for the year 1965, based on 10% thickening, were estimated at 223,000 tons. For the year 1980, this figure will be increased to 247,000 tons.

Barges of 3000, 4000, and 5000 tons were studied. For the purpose of comparing this project with others, a 4000-ton barge was selected. Factors used in the selection were the relative number of round trips per year, the towing time to the disposal area and return, time allowance for repairs and bad weather, and storage capacity in lagoons to take care of delays. The 4000 ton barge will require 56 annual round trips in 1965, increasing to 62 in 1980. Time under way for the round trip from the plant to disposal are and return is approximately 39 hours.

Construction costs for projects E2 are as follows:

Lagoon excavation	$ 125,000
Barge - 4000 tons	805,000
Initial Dock Dredging	30,000
Pipe Lines, etc.	39,000
Dredge and Pontoon Line	150,000
Engineering, Contingencies, Misc.	230,000
	$1,379,000

Annual operating costs, using the 4000 tons barge, and the 1965 requirements are:

Labor	$ 4,000
Electricity	700
Towing @ $40.00 per hour	93,600
Maintenance	14,700
Replacement of equipment	3,600
Dredging of dock	4,000
Debt Service	74,900
	$ 195,500

For the purpose of this study, the construction of a 4000-ton barge by the City was used, since preliminary search had failed to reveal any available barges of this capacity in the east coast area. At such time as the project goes forward, an alternate scheme will be explored in which a 5 or 10 year contract will be awarded, with the successful bidder constructing the barge, and furnishing all the disposal services.

Project F

Earlier studies had been made in Philadelphia for the disposal of sludge as fertilizer, but markets were apparently not available. The same situation was deemed to exist for compost products. Because of this and the lack of experience on large scale composting products, this method was not considered in any detail.

Project G

This project is an intermediate step between Projects "D" and "K", which would include the dewatering facilities of these projects. It is listed only as an indication of the exploration of all possible steps. It was not deemed desirable to proceed with any detailed studies of this method.

Project H

This project would dispose of wet digested sludge by discharge directly to the Delaware River at the Northeast plant. It is obviously the cheapest of all methods considered, since the only cost would be the short extension of the present pipe lines from the lagoons to the river, and the necessary underwater piping to the main channel.

The project was discarded as impractical for several reasons:

(a) The channel of the river from the sea to Philadelphia and above must be continually dredged to accommodate the large amount of shipping using the port. This channel is now being increased in depth from 25' and 35' to a 40' channel. Any settling of solids in the channel would have to be removed.

(b) There is considerable fishing and oyster farming in the lower Delaware Bay. Discharge of large amounts of sludge would certainly be considered detrimental to this industry.

(c) Aside from all engineering and scientific reasons why sludge could be discharged directly into the river, there are some amenities involved in a situation where a large city shares a river with other communities in its own state, and in two other states. There are practical limits to these amenities, but for this project, they exist to such a degree, in connection with reasons (a) and (b), that no further consideration was given to its use.

Project I

This is a variation of Project "A", except that instead of pumping the sludge from Northeast Works to Southeast Works, a distance of 7 miles, it would be pumped only to the upper end of the Southeast Works intercepting system, a distance of only 2 miles. At this point it would flow by gravity to Southeast Works, mixing with regular sewage for that plant. Studies of the problems of removing the digested solids when mixed with fresh sewage solids, indicated a possible adverse effect on the treatment process at Southeast Works, and no further consideration was given to the project.

Project J

This is similar to Project "I", except that the digested sludge for Northeast Works could be pumped to the head of the Southwest intercepting system. Because the pumping distance was longer, and for the same reasons given under Project "I", no further study was made of this method.

Project K

This consists of elutriation, dewatering and incineration of sludge, and was the project originally considered in 1946 as the successor to lagooning, when the lagoons became filled. Full consideration was given to this plan, especially in view of the fact that detailed construction plans were in an advanced state of preparation.

Work required for this project includes two elutriation tanks, each with a capacity of 45,000 cu. ft., six vacuum filters with 600 square feet per unit, three incinerator units, each with a rated capacity of 180 tons of sludge cake per 24 hours, together with the piping, chemical storage, and ash handling facilities.

Total sludge quantities were given earlier in this paper. The estimated amounts of sludge cake at 25% solids are:

Annual Average 1965 -	358 tons
Annual Average 1980 -	397 tons
Maximum Month 1980 -	530 tons

Construction costs of this project are estimated as follows:

Elutriation -	Construction	$ 95,000
	Equipment	50,000
Dewatering	Construction	1,237,000
	Equipment	
Incineration	Equipment	1,000,000
Misc.		60,000
Engineering & Contingencies		560,000
		$3,362,000

Annual operating costs were estimated at $623,730 as follows:

Labor	$ 144,000
Power	16,190
Fuel	51,200
Chemicals	111,300
Maintenance	86,540
Replacement of Equipment	31,500
Debt Service	183,000
	$ 623,730

Many of the above costs, both for operation and construction were difficult to estimate, and some are subject to revision. In general, they are based on the same factors used in other projects, and on the same engineering judgment.

Based on the 1965 average of 22,265 tons per year, the annual cost of $623,730 gives a cost per ton of $28.01. Since this figure was considerably higher than some other projects considered, some checking was done at other locations to determine if this figure of $28.01 was in line. Procedures, costs, and methods of calculatory cost vary somewhat, but a check at four locations gave figures of $40.00 per ton and above. This determination was made only to make certain that the estimated unit figures for Philadelphia were not excessive.

A variation of this project which is now under consideration calls for elutriation and dewatering of sludge, and the incineration of the sludge, using hot gases from a refuse incinerator, operated by the City of Philadelphia on a site immediately adjacent to the Northeast Works. Further study will be made of this project, in light of the problems which have arisen in connection with the selected project, as described later in this paper.

Project L

This project calls for continued use of the lagoons at Northeast, and excavation and hauling of sludge to the lagoon area at Southwest Works when it reaches 18% solids. In estimating this work, it was considered that the excavation and hauling would be done by contract under competitive bids. The annual average in 1965 per working day (5 days per week) was estimated at 475 tons, or 542 cubic yards. Based on a cost of $2.00 per yard for excavation,

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hauling, and unloading, the annual cost has been estimated at $282,000. This project is also involved in the consideration of the future use of the land at Southwest Works.

Cost and Other Considerations

For preliminary consideration, cost estimates were prepared of the total initial capital cost, annual operating costs, and debt service. Debt service was calculated using 30 year bonds at 3-1/2% interest. The total annual cost was then reduced to a cost per ton per year of dry solids. These costs are shown on Table 2.

In making the selection of best project, some additional factors other than unit annual cost of disposal of solids were considered. Some of these were:

(a) The size of the capital investment required, particularly on those projects where developments in the art of sewage treatment during the life of the bonds may make the project obsolete or costly. This applies especially to Project K for incineration with the highest capital investment of $3,362,000 and Project B in which there would be an investment in 66,000 feet of force main, which would have little or no use after lagoon space at Southwest Works was filled.

(b) The operating problems, both as they affect the efficiency of the treatment plants, and as they affect other persons or communities. Some of these are the mixing of digested solids with raw sewage, such as in Projects "I" and "J", the effect on other communities in Projects E1, E2, and H, and the hauling of sludge or sludge cake through streets of Philadelphia, as in Project C1, C2, and D.

(c) An estimate of future developments in the field of sewage treatment, both in the overall aspect and in Philadelphia. From the overall viewpoint, this was more of a conditioning factor in judgment, rather than a specific one, but there are bound to be changes and new developments. From the Philadelphia standpoint, the development of the metropolitan area in Delaware Valley will bring many changes, one of which will probably be a change in treatment methods at Southwest and Southeast Plants from primary to secondary treatment, and perhaps a higher degree of treatment than now practiced at Northeast Works. This will result in more sludge for disposal, and a shortening of the time in which the present area at Southwest can furnish lagoon capacity.

(d) The specific question of whether the space now available at Southwest for lagoons can continue to be reserved for such use. The site is immediately adjacent to the Philadelphia International Airport. It is surrounded by large refineries, and an increasing number of industries, and has some water frontage on the Schuylkill River. Some of the original site has already been allocated for airport use. In view of the increasing value of this land, a point will come when it will be more economical to sell the land and find other means of sludge disposal, rather than retain it for disposal on the site. Calculations to determine this point have many variables, and no definite figures can be used, but this

Table 2, Cost Comparison of Sludge Disposal Projects

Project	Description	Construction Cost	Annual Cost			Annual Cost per ton of Dry Solids
			Operation	Debt Service	Total	
B.	Pumping wet sludge to Southwest Lagoons	2,330,000	35,300	125,700	161,000	7.23
C1.	Trucking wet sludge to Southwest Lagoons-5% solids	886,800	344,500	48,200	392,700	17.64
C2.	Trucking wet sludge to Southwest Lagoons-10% solids	1,359,000	194,300	73,900	268,200	12.05
D.	Trucking sludge cake to Southwest	1,747,000	325,400	95,000	420,400	18.90
E1.	Barging wet sludge to sea - 5% solids	1,038,000	206,400	56,500	262,900	11.81
E2.	Barging wet sludge to sea - 10% solids	1,379,000	120,600	74,900	195,500	8.78
K.	Dewatering and Incinerating Sludge	3,362,000	440,730	183,000	623,730	28.01
L.	Excavating lagoons at intervals - Trucks 18% solids to Southwest	0	282,000	0	282,000	12.67

factor weighed heavily in considering projects which would have centered all sludge disposal at Southwest Works.*

Selection of Project

Project E2, barging to sea, was selected as the most desirable after weighing all possible consideration. The unit cost of $8.78 was second lowest, and considerably lower than most others. The capital investment of $1,379,000 was in the median range of those projects requiring capital investment, and this might be reduced further if private interests could be induced to construct the necessary barge. This project does not require use of the Southwest site, and it makes no serious commitment of method or procedure which could not be changed to meet new technological advancement. It was considered to be a project which would be acceptable to the immediate community, and to all others involved. And hereby hangs a tale.

This paper would be one describing the start of operations on the selected procedure, rather than a discourse on methods, if the final assumption noted above had been true.

Although the ocean disposal area chosen was at a point at least 11 nautical miles from the nearest shore, and at a point from which currents would not flow back to the shore, it was considered that the adjacent states of New Jersey and Delaware would have some interest in the plan, and should be consulted.

Prior to any public announcement, the matter was referred to appropriate public agencies in these states. It was discussed at length, both in writing and verbally, with the technical staffs of these agencies.

At one point, serious consideration was given to the disposal of the sludge on waste land in New Jersey, bordering on Delaware Bay. Although not practical at this time, further consideration is being given to this plan by New Jersey authorities. If desirable in the future, the selected project of barging to sea can easily be modified to this method of disposal.

After complete study by agencies of the two states, Philadelphia was notified that there was no objection to the procedure, subject only to such conditions that careful study and observation be made of the work, and that any serious problems be corrected.

Formal application was then made to the District Engineer of the Corps of Engineers at Philadelphia for a permit for the work. There was some discussion concerning the scope of authority in such a permit, but since navigation in the river and bay was involved, the permit was requested and the District Engineer gave public notice of the request.

This brought forth a large number of complaints from the seashore resort cities in southern New Jersey, and in Delaware, and from some individuals, and recreational and commercial associations. Many public statements were

*In November 1958, an area of 200 acres at Southwest Works was set aside by the City Council for development for industrial purposes, with the arrangement that the self-sustaining Water Department be reimbursed in some manner for the loss of this land. The measure of reimbursement has been suggested to be the difference between the cost of lagooning on the site, and the cost of the alternate method of sludge disposal.

made denouncing the plan, but most of them were based on incomplete and inaccurate information. Typical of these was the charge that raw garbage was to be dumped in Delaware Bay.

The matter has been allowed to lie dormant over the summer of 1958, with the hope and attempt that some method may be found to show the objectors that the proposed discharge of digested sludge 11 miles offshore will not harm resort communities or effect fishing interests. It is the belief of the Philadelphia Water Department staff that there will be no physical evidences of these finely divided solids on the beaches, and that there will be no health hazards involved. From the standpoint of fishing, it is possible that the nutrient in the sludge may help the fishing.

The Water Department has asked Incodel (The Interstate Commission of the Delaware River Basin) to act as an unbiased agency to bring together the various interests involved, and to attempt to reach an understanding and a solution. The Commission agreed to do this at their meeting on October 3rd, 1958, and the future of sludge disposal in Philadelphia is tied up in the results of meetings which are proposed to be held under the sponsorship of this agency.*

This paper is based on a report prepared for the Philadelphia Water Department by Greeley and Hansen, Consulting Engineers of Chicago, and in collaboration with the Water Department staff. Mr. Samuel A. Greeley, Hon. M. ASCE, and Richard H. Gould, M. ASCE, represented Greeley and Hansen. The Water Department participants were Max Barofsky, M. ASCE, Deputy Commissioner, Alexander Maltman, A. M. ASCE, Chief of Design Branch, Ralph A. Hoot, Chief of the Sewage Treatment Division, and the writer.

*The first meeting was held on November 7, 1958, with representatives of the State Health Departments of Pennsylvania, New Jersey, Delaware and Maryland.

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ENGINEERING CONTROL OF AIR POLLUTION IN LOS ANGELES COUNTY[a]

Robert L. Chass[1]

ABSTRACT

The author describes and illustrates the major types of devices installed by industry in Los Angeles County to control the emissions of air contaminants. Over the past ten years, an expenditure of more than 70 million dollars has prevented more than two thousand tons of air contaminants from entering the Los Angeles atmosphere each day.

As a result of intensive efforts over the past ten years by industry and the Los Angeles County Air Pollution Control District in the field of air pollution control engineering, remedies now are available for most types of industrial air pollution problems. Solutions to most urban air pollution problems in the United States now can virtually be "bought off the shelf". No longer is there any excuse for excessive industrial air pollution in this nation.

The installation of $70,000,000 worth of control equipment by Los Angeles County industry has resulted in preventing more than 2,000 tons of air contaminants from entering our atmosphere each day. Without these controls, air pollution conditions in this area would be infinitely worse, possibly injurious to human health and safety.

As in other areas throughout the country, the air pollution control program of Los Angeles County has been aimed primarily at the elimination of the public nuisance problems generated by smog and has not been stimulated by the health aspects of the problem. Based on inauguration of proper control measures for each significant source of air pollution contributing to these nuisance problems, the control program is guided by the assumption that the

Note: Discussion open until April 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2267 is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. SA 6, November, 1959.

a. Presented at the February 1959 ASCE Convention in Los Angeles, Calif.

1. Director of Engineering, Los Angeles County Air Pollution Control District.

full control of these sources will lead to acceptable reductions in the overall problem and thereby render all but impossible the occurrence of a public health disaster.

Even should the medical profession succeed in establishing without any doubt that air pollution does cause deaths, it is doubtful if the control of air pollution in this area could be advanced more quickly. Whether or not smog is damaging to health, the six million residents of Los Angeles County have been unanimous in their contention that they just do not want smog.

If a community wants its air supply pure enough to meet local requirements and demands, then the community must be willing to pay a certain price. In Los Angeles the price has been high because the control program was a pioneer effort. The price in other areas should be much lower because of that effort. Results, answers and techniques now are available that can be of benefit to many other areas. It would be a shame to repeat the experiences in Los Angeles in every urbanized area. The mistakes and accomplishments in Los Angeles can be guide lines for other areas to follow and the price the community pays, therefore, should be far less than it has been for Los Angeles.

Air Pollution Disasters

During the past decade there has been a growing public awareness of air pollution in most densely populated urban areas of the world. The occurrence of air pollution attacks of disaster proportions in London, England; Donora, Pennsylvania; Meuse Valley, Belgium; Poza Rica, Mexico; and other places has brought into public focus the potential danger of this newest problem in urban growth.

From December 1 - 5, 1930, in the part of Belgium along the Meuse River, between Leige and Huy, several hundred persons were severely attacked by respiratory ailments. Sixty-three persons died on December 4 - 5 after only a few hours of sickness. Many head of cattle had to be slaughtered.

In October 1948, some 20 people died in Donora, Pennsylvania, as a result of a severe air pollution condition. Some 42 per cent of Donora's 14,000 population was affected. Severity of the effects to almost 6,000 people did not appear to be influenced by sex, race, occupational status, length of residence in the area, or the degree of physical activity at that time. In addition to the persons who became ill during the smog attack, domestic animals also became ill and some died.

On November 24, 1950, 22 people died as a result of atmospheric pollution in the refining town of Poza Rica, Mexico. Some 320 people were hospitalized. The houses in which deaths occurred were at a distance of 350 to 1,000 feet of the base of the source believed to be responsible for the trouble. Poza Rica is a town of 22,000 people, 30 miles inland from the Gulf of Mexico.

Between December 5 and 8, 1952, a high pressure system of relatively cool air settled over the London Basin and marked an unusually prolonged period of almost complete calm. A low temperature inversion from 200 to 500 feet in height was created. It was into this stable, shallow mass of fog-laden air that there was poured four days of emissions from the chimneys of London and from the exhausts of vehicles. In the greater London area for the week ending December 13, 1952, the number of reported deaths was 4,703, as compared to totals of 2,062 for the week ending December 6; 1,902 for the week ending November 29; 1,699 for the week ending November 22; and 1,565 for the week ending November 15.

It is interesting to note that in all of the aforementioned incidents extremely unusual weather conditions were superimposed abruptly upon an area having unique topographical formations. In no case, other than in Poza Rica, did it appear that the emissions into the atmosphere were other than normal.

The Los Angeles Basin

Los Angeles and its environs have special and peculiar problems. Los Angeles County is the largest heavily-industrialized, semitropical area in the world. It comprises 4,083 square miles and contains 63 incorporated cities and large scattered unincorporated areas. Its population has more than doubled since 1939 and industry has expanded from approximately 6,000 establishments in 1939 to more than 16,000 in 1958.

Topographical and meteorological conditions aggravate the effects of the pollution produced by this population and this industry in the Los Angeles Basin. The average wind velocity is less than six miles per hour. Such light winds as do develop are made relatively ineffective in their job of carrying off the polluted air by a condition of temperature inversions which prevail approximately 260 days of the year. The height of the inversion base varies from ground level to 3,000 feet. These inversions have been most noticeable during the summer months, but in the last few years extreme inversions have occurred in the November-December period as well. The effect of the temperature inversions is to limit the vertical distribution of the atmospheric pollution while the local winds move the air over the area from the west during the day.

In Los Angeles County, the complex mixture of smoke, dusts, fumes, gases, and other solid and liquid particles in the atmosphere is called "smog". This smog may produce a single effect or a combination of eye irritation, throat irritation, reduced visibility, damage to vegetation, rubber cracking, local nuisances, and a host of other complaints, real and fancied.

Any community which suffers from an air pollution problem must inevitably turn its attention to the operations of industry. Historically, it is these operations that are most frequently associated with community air contamination problems. In keeping with this tradition, it was to these activities that the Los Angeles County control program was first directed.

The State Law

In 1947, the California Legislature passed Assembly Bill No. 1, which was an act adding Chapter 2 to Division 20 of the Health and Safety Code relating to the control and suppression of air pollution. It was approved by the Governor on June 10, 1947. At an open hearing on October 14, 1947, the Board of Supervisors of Los Angeles County, after finding that the air within Los Angeles County was so polluted with air contaminants as to be offensive to the senses of a considerable number of persons, adopted a resolution declaring the need for and creating an air pollution control district.

The passage of Assembly Bill No. 1 established the necessary machinery whereby additional rules and regulations could be enacted by the Air Pollution Control Board to accomplish the purposes of the law and for the proper administration of the District. The statute is drawn sufficiently broad to enable the District to enact new and more stringent prohibitions when the needs for

such prohibitions are found and when the technical information is made available upon which to base them. The statute also established a means whereby the District could put into effect a permit system requiring that all equipment capable of emitting air contaminants would first be reviewed by the Air Pollution Control Officer. Since the Health and Safety Code states that the boundaries of every air pollution control district shall be co-extensive with the boundaries of the county within which it is situated, the Air Pollution Control Officer no longer had to concern himself with city boundaries. The District has jurisdiction over the entire county. The Code also gives the Air Pollution Control Officer the right to enter a building, premise, or other place for the purposes of enforcing or administering any order or regulation. It also made it possible for the Control Officer at any time to require from an applicant or holder of any permit information, analyses, plans or specifications that would disclose the nature, extent, quantity, or degree of air contaminants which could be discharged from such a source.

Under the provisions of the law, a Hearing Board is established which has the right to hold hearings to determine under what conditions and to what extent a variance from the requirements is necessary and will be permitted. In determining under what conditions and to what extent a variance is necessary and will be permitted, the Hearing Board is given the right to exercise wide discretion in weighing the equities involved and in weighing the advantages and disadvantages to the residents of the district and to any lawful business.

To meet constitutional requirements, air pollution control rules and regulations must not be unreasonable, they must not be capricious, they must not be arbitrary, and they must not be confiscatory. Evidence must be provided by the District showing that compliance with the standards imposed by the rule is possible and that persons will not be denied their rights to engage in lawful occupations. In essence, this requirement means simply that a "reasonable" solution must be available before any industrial source problem can be solved through legal compulsion. In short, our engineering and control technology must stay one pace ahead of our legally compulsory control enactments.

Rules and Regulations

The Rules and Regulations now contain the following 14 rules under Regulation IV—PROHIBITIONS:

Rule 50—RINGELMANN CHART establishes the maximum permissible time and opacity limits for the discharge of any contaminant.

Rule 51—NUISANCE defines a nuisance.

Rule 52—PARTICULATE MATTER establishes the maximum allowable limits for the discharge of particulate matter.

Rule 53—SPECIFIC CONTAMINANTS establishes the maximum allowable limits for the discharge of sulfur compounds and combustion contaminants.

Rule 53.1—SCAVENGER PLANTS sets forth the conditions under which a scavenger plant may operate.

Rule 54—DUST AND FUMES establishes the maximum allowable limits for the discharge of dusts and fumes.

Rule 56—STORAGE OF PETROLEUM PRODUCTS sets forth the type of control equipment that can be used for the control of hydrocarbons from the storage of gasoline and certain petroleum distillates.

Rule 57—OPEN FIRES bans the practice of burning combustible refuse in the open.

Rule 58 and 58.1—INCINERATOR BURNING ban the use of single chamber incinerators.

Rule 59—OIL EFFLUENT WATER SEPARATORS sets forth the type of control equipment that can be used for the control of hydrocarbons from oil-water separators.

Rule 60—CIRCUMVENTION prevents the use of equipment which would tend to conceal the emissions of air contaminants without actually resulting in the control of pollution.

Rule 61—GASOLINE LOADING INTO TANK TRUCKS AND TRAILERS sets forth the type of control equipment that can be used for the control of hydrocarbons from the loading of gasoline into tank trucks.

Rule 62—SULFUR CONTENT OF FUELS bans the use of high sulfur fuel oils six months each calendar year.

It can be seen from this impressive list of prohibitions that the Rules and Regulations affect the operation of every industry located in Los Angeles County. Through their enforcement, controls have been applied to such diverse sources and operations as incinerators, open fires, coffee roasters, petroleum refineries, chemical plants, rock crushers, and asphalt plants. From the smelting of metal to the painting of manufactured goods, industrial operations have been brought within the scope of the control program.

Engineering Control Equipment

In February 1948, the Board of Supervisors adopted the first rules and regulations which established the permit system. Under these rules, every source capable of emitting air contaminants constructed since that date has required an authority to construct and a permit to operate from the District. From April 1948 through December 1958, 32,590 permits were issued by the District, of which 25,300 were for basic equipment costing $454,181,000 and 7,290 for control equipment costing an additional $70,212,000. During this same period 4,630 applications were denied, for both basic and control equipment valued at $176,600,000.

The more than 7,000 air pollution control devices installed in industrial plants vary widely in cost and collection efficiency. Among them are the following major types:

1. ELECTRICAL PRECIPITATORS are used to separate and collect particulate matter from waste gas streams. The control device contains oppositely charged, high voltage plates and wires. The solid materials in the gas stream are given an electrical charge by the wires, and then are attracted to the oppositely charged plates. Periodically, the particulate matter deposited on the plates are "rapped" or washed off and collected for harmless disposal.
2. BAGHOUSES also are used for the collection of particulate matter, and function much like the household vacuum cleaner. Waste gas streams are fed to baghouses through inlet headers which allow the gas to be introduced under pressure into the bags. The house itself consists of a number of tubular bags made of glass fiber, felt, or other similar material. In passing through the bags and into the atmosphere, the gas

stream is cleansed of the contaminants which are collected in the bags. The filtered particulate matter is removed by stopping the gas flow and shaking the bags, allowing the material to be collected in hoppers.

3. FUME BURNERS incinerate the combustible materials contained in a waste gas stream. Devices of this sort consist of a refractory lined shell equipped with one or more natural gas burners. Time and temperature are most important factors in the ultimate efficiency of such a device.
4. COLLECTORS AND SEPARATORS of various types also are used to collect solid materials. Cyclone separators employ the principle of centrifugal force to throw the solids out of the swirling gas stream, and therefore function much like a cream separator. Settling chambers may be used to collect large solids. These function by slowing the gas stream to permit the fall-out of heavy particles into the settling chamber. Another technique permits the collection of solids by passing the gas stream over cooled or heated plates which collect the solid materials. Sonic precipitation uses high frequency sound waves to cause the particles to collide and cling together. These larger particles then can be removed easily through settling processes.
5. SCRUBBERS AND WASHERS cleanse particle-laden gas streams by use of a spray which strikes the solids and washes them from the gas. Gas may also be bubbled through a liquid bath for cleansing.
6. VAPOR COLLECTION EQUIPMENT is used to capture vapors generated during the storage or handling of gasoline and other petroleum products. The vapors are drawn from storage vessels through vent pipes to collection equipment such as vaporspheres. The control system may provide for compressing the collected vapors back into a liquid state, or may process them for removal by absorbers or incinerators. In some cases the vapors can be used to fire boilers, or they can be incinerated in a fume burner.
7. ABSORBERS involve a process in which one material is employed to take up and retain another. They are used to selectively remove a gaseous or liquid material from another gas or liquid. Usually, the process is performed in cylindrical towers which are packed with an absorbing material. Representing a very large absorbing area, the packing serves to spread the liquid or gases and thus hastens and makes more efficient the absorption process.
8. ADSORBERS also are employed in the control program. They involve a physical process in which the molecules of either a gas or a liquid are captured by a solid material. Usually, the capturing solid is activated carbon which has a large surface area in the form of very small tubes, called capillaries. The molecules to be removed are passed over the activated carbon where they enter, and are captured by, the capillaries. The carbon can be regenerated by steam which drives off the adsorbed material in the form of a vapor which is then condensed along with the steam.

Each type of device possesses advantages and limitations that must be considered carefully. Each source poses different problems in terms of the volume, temperature, and characteristics of the waste emitted from it. In effect, a solution must be tailormade to the source. The degree of control which a community requires will dictate, in the main, which type control will be utilized and the cost of the control system.

In staying at least one pace ahead of the problem the District's control program has produced many engineering "firsts" during the past ten years. The type of equipment and approximate costs involved are illustrated on the following pages.

Los Angeles County "Firsts" in Air Pollution Control

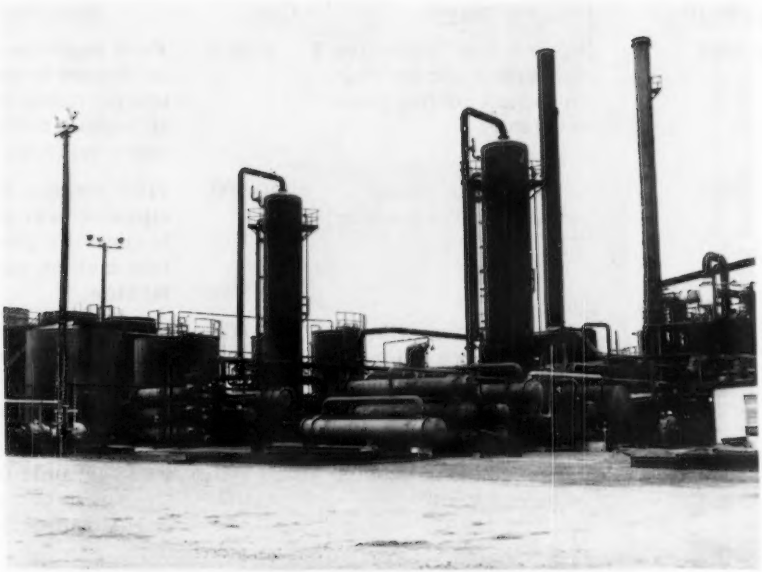
Date Placed in Operation	Equipment	Cost	Remarks
Jan. 1948	Exhaust system with baghouse serving brass melting crucible furnaces	$ 4,000	First brass furnaces of this type to be controlled.
Aug. 1949	Exhaust system and baghouse serving an electric steel melting furnace	2,500	First electric steel furnace ever to be controlled with a baghouse.
Feb. 1950	Afterburner serving a coffee roaster	1,800	First coffee roaster ever equipped with afterburner.
June 1950	Afterburner for a varnish cooking kettle	2,000	First direct fired afterburner and the first really satisfactory control device on a varnish kettle.
Aug. 1950	Exhaust system and electric precipitator with waste heat boiler serving an open hearth steel melting furnace	150,000	First open hearth furnace to have satisfactory air pollution control equipment.
Nov. 1950	Electric precipitator serving an aluminum dross recovery plant	30,000	First dross recovery plant ever controlled by a precipitator.
Dec. 1950	Chemical plant to recover elemental sulfur from refinery waste hydrogen sulfide	1,150,000	First chemical plant in Los Angeles County to recover waste hydrogen sulfide gas and convert to elemental sulfur.
Jan. 1951	Exhaust system, quencher and baghouse serving two iron melting cupola furnaces	15,000	First iron cupola ever to be satisfactorily controlled.
Feb. 1951	Baghouse serving a galvanizing kettle	1,000	First baghouse to serve a galvanizing installation.

Direct gas-fired afterburner serving 4 varnish cooking kettles. System is rated at 1,000 cfs.

Baghouse consisting of 240 cloth tubes with 2880 square feet of filtering area controls emissions from 4 brass melting furnaces.

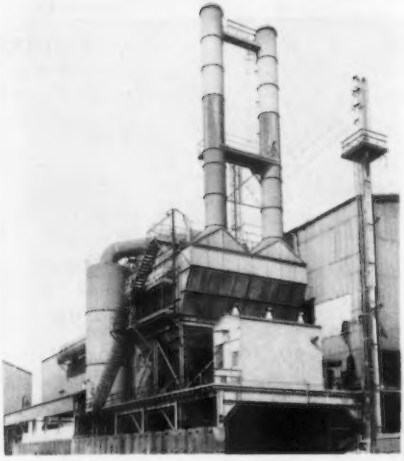
Baghouse consisting of 1200 tubes with a cloth filtering area of 24,000 square feet controls emissions from 4 electric steel furnaces.

Date Placed in Operation	Equipment	Cost	Remarks
May 1951	Water spray cooler and baghouse filter serving an asphalt roofing paper saturator.	$ 25,000	First baghouse ever to be used to control oil mists from an asphalt roofing paper saturator.
Jan. 1952	Electric precipitator serving an iron melting cupola	40,000	First electric precipitator ever used to control a gray iron melting cupola furnace.
Jan. 1952	Exhaust system with electric precipitator serving two 75-ton and one 50-ton electric steel melting furnaces	650,000	First satisfactory installation ever to control large electric steel melting furnaces.
Feb. 1952	Pease—Anthony Venturi —Cyclone scrubber	25,000	First ceramic frit smelter to be controlled satisfactorily.
Apr. 1952	Exhaust system with afterburner and baghouse serving aluminum sweat furnace and a rotary aluminum chip dryer	6,000	First really satisfactory installation ever to control such non-ferrous operations.
Feb. 1953	Water scrubber serving galvanizing kettles	12,000	First control device capable of controlling odors and gases from a galvanizing operation.
Feb. 1953	Boiler firebox and crude oil absorber serving refinery waste water system	340,000	First controls for a refinery waste water system in which separator is covered and collected gases are absorbed and incinerated.
June 1953	Water scrubber coupled with electric precipitator for controlling fumes from fluxing of aluminum in a reverberatory furnace	45,000	First such control system ever installed for the combined problem of fluoride and chloride fluxing fumes.
July 1953	Electrostatic precipitator serving an asphalt roofing paper saturator	40,000	First two-stage electrostatic precipitator ever installed to control a roofing paper saturator.



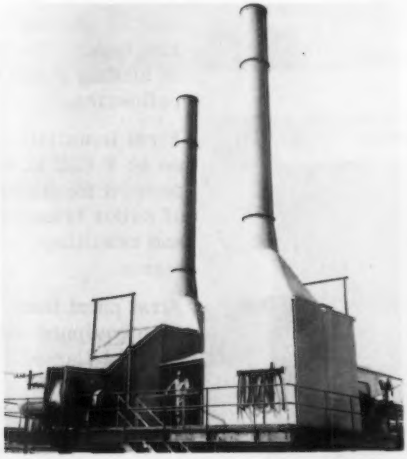
Four electrical precipitators, each preceded by a waste heat boiler, control emissions of dusts and fumes from 4 open hearth steel furnaces.

A chemical plant recovers elemental sulfur from refinery waste gas containing hydrogen sulfide.



Dust and fume emissions from 75-ton and 50-ton electric steel melting furnaces controlled by electrical precipitator.

Gray iron melting cupola controlled by exhaust gas conditioner and electrical precipitator, handling 18,000 cfm of gas at 500° F.



Two-stage electrostatic precipitator and precleaner control emissions from asphalt saturator. System is rated at 22,000 cfm. Precleaner consists of sprays, metal mesh filters and mist eliminator.

Two water scrubbers, each with 30,000 cfm capacity, control emissions from a galvanizing kettle.

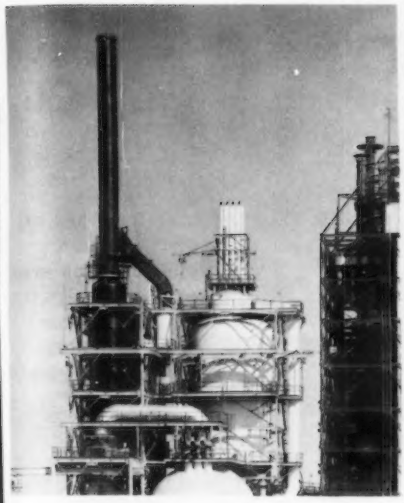
SA 6

Date Placed in Operation	Equipment	Cost	Remarks
Nov. 1953	Water scrubber for control of fumes from airblown asphalt manufacture	$ 45,000	First installation ever to use a sea water scrubber.
Nov. 1953	Sour Water oxidizer to convert odorous sulfides into water-soluble thiosulfates	30,000	First installation for disposal of sulfides in effluent water as contrasted to standard method of burning to sulfur dioxide.
Dec. 1954	Absorber unit employing gasoline as the absorbing medium for recovery of vapors collected from bulk loading of tank trucks	40,000	First installation of its type ever to be designed and installed.
Jan. 1956	Vapor collection system for gasoline loading rack at refinery	30,000	First vapor collection system to collect escaping hydrocarbon vapors released in bulk loading of gasoline into tanker trucks at loading racks in refineries.
April 1956	Flue gas heater serving a Fluid Catalytic Cracking Unit	80,000	First installation on an F.C.C.U. to prevent formation of sulfur trioxide and resulting plume.
April 1956	Direct flame afterburner on a paint bake oven	5,000	First paint bake oven equipped with a direct flame afterburner to control emissions.
April 1956	Direct flame afterburner serving meat smokehouse	4,000	First direct flame afterburner ever installed on a meat smokehouse.
Oct. 1956	Baghouse with radiant cooling ducts on glass furnace	8,500	First installation of control system on glass furnace.

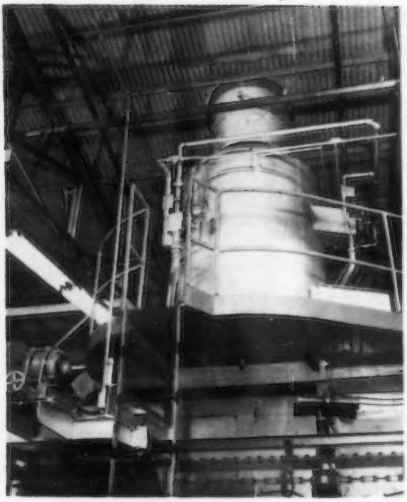
Emissions from plastic curing oven controlled by a direct fired afterburner.

Electrical precipitator controls emissions from a meat smoking operation.

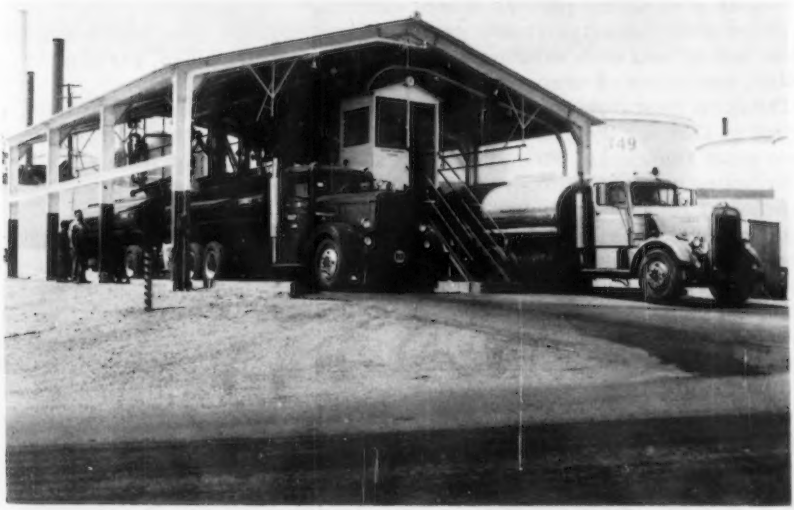
Date Placed in Operation	Equipment	Cost	Remarks
Nov. 1956	Scrubber coupled with an electrostatic precipitator serving meat smokehouses	$ 10,000	First such control device ever installed to control smoke from smokehouses.
Mar. 1957	System for control of discharge from coker unit blowdown, consisting of water scrubber, condensers and final discharge to refinery flare	385,000	First system for control of hydrocarbons from coker unit blowdown.
Oct. 1957	Exhaust system with baghouse serving four stereotype metal melting pots	9,000	First such controls ever installed at a printing establishment to control metal melting operations.
Jan. 1958	Direct fired afterburner serving plastic curing oven.	2,800	First afterburner ever installed to control the discharge from a plastisol curing oven.
Feb. 1958	Activated carbon adsorber installed to control solvent losses from dry cleaning plant	4,000	First such installation for this type cleaning plant.
Mar. 1958	Direct fired afterburner on a large paint baking oven	16,000	First installation of its kind on an automobile paint bake oven.
Mar. 1958	Activated carbon vapor adsorber on a five-color rotogravure printing press	48,000	First regenerative activated carbon adsorber unit serving rotogravure press and which was installed strictly for air pollution control purposes.
Mar. 1958	Activated carbon adsorber serving 47 paint mixing tanks	10,000	First such installation made at an automobile manufacturing plant for the purpose of controlling solvents.



Direct flame gas fired afterburner used to control hydrocarbon emissions from a paint baking oven.



Flue gas heater, serving a fluid catalytic cracking unit, prevents the formation of sulfur trioxide plume.



Collection system for hydrocarbon vapors at a refinery gasoline loading rack handling 600,000 gallons of gasoline per day.

SA 6

Date Placed in Operation	Equipment	Cost	Remarks
Apr. 1958	Catalytic afterburner on paint bake oven in an automobile assembly plant	$ 70,000	First catalytic afterburner installed to control paint baking oven in an automobile assembly plant.
To be completed in 1959	Electric precipitator serving a 1,254,000 lb. per hour oil burning steam generator	1,000,000	First time any oil burning steam generator has ever been equipped with an air pollution control device other than controls for soot blowing.

Remaining Problems

1. Fuel Oil Burning

With the fulfillment of activities directed toward these two broad industrial pollution problems, the major portion of our industrial control effort will have been brought to the point of completion.

None of the 71 boilers now operating in 12 steam power plants in Los Angeles County are equipped with air pollution control devices other than dust collectors used during periods of soot blowing.

These units discharge visible smoke emissions when fired with heavy residual fuel oil and emit substantial quantities of sulfur oxides, particulate matter, and oxides of nitrogen.

The Joint Research Council on Power Plant Air Pollution Control was formed in 1956 for the express purpose of eliminating air contaminants from power plant flue gases. Since then a great deal of money has been spent by participating power plant operators, both on the study of plume formation and on means of removing pollutants.

An important result attributable to this research is the installation just completed by Southern California Edison Company of a one million dollar electrical precipitator at their El Segundo facility to remove more than 90 per cent of the particulate matter from exhaust gases.

Strong efforts have also been made to secure additional natural gas supplies so that fuel oil burning can either be eliminated or restricted to periods when weather conditions are not conducive to smog formation. This approach toward reducing air pollution from power plants has been carried to the point of preparing legislation and introducing it at a public hearing on October 22 of this year. During the period encompassed by the proposed rule, legislation would prevent the daily emission of approximately 400 tons of contaminants from the burning of residual fuel oil.

2. Organic Solvents

In the industrial, commercial and domestic activities carried on in Los Angeles County many different solvents are used which are eventually

Direct-fired afterburner controls solvent emissions from automotive paint bake oven. Heat from the hot gases discharged from the afterburner are reclaimed in an adjacent oven.

Emissions from 175 megawatt steam electric generating power plant unit controlled by an electrical precipitator handling 472,000 cfm at 275° F.

vaporized into the atmosphere. Alcohols, ethers, paint thinners and lacquer thinners are included in the definition of organic solvents. These organic solvent vapors react in the Los Angeles atmosphere to produce smog in the same manner as gasoline vapors.

The District presently is measuring the reactivities of individual solvents and rating them in respect to their capabilities for smog formation. The most recent estimates indicate that about 400 tons per day of these solvents are discharged into the atmosphere.

Control of organic solvents has presented three basic problems typical of air pollution control—control development, chemical identification and legal regulation.

Determination of suitability of known control measures, and development of adequate control devices where none formerly existed, are the most readily recognized problems. To evaluate control measures implies the availability of accurate and readily usable methods of air contaminant measurement. Answers to these two problems then permit the establishment of rules limiting the losses from specific sources. As there are at present no rules limiting these sources, solutions to these three phases are being developed concurrently.

Analytical methods must be found that are adaptable to field measurements, that will measure quantitatively the wide variety of organic chemicals encountered and that will provide reproducible results. The APCD is at present evaluating three separate methods, and a satisfactory solution is believed to be found imminent.

Enactment of a rule regulating all solvent emissions must await the establishment of reasonable emission standards and the development of suitable methods for measuring vented contaminants. Initial drafts of possible rules presently are being evaluated by the APCD. It may be possible, however, to enact legislation effectively covering some of these sources before all answers to the overall problem become apparent.

3. Automobile Exhausts

It is apparent that the complete solution to the smog problem in this area hinges on the success in equipping each of the three million automobiles registered in Los Angeles County with a device to control effectively the emissions of hydrocarbons from the exhausts. Once an effective device is available, a motor vehicle inspection system will have to be organized and put into motion at the earliest possible date. There is good reason to believe that such a system will require cooperative action between the District and agencies of the State of California.

The District has full intentions of requiring the installation of control devices on motor vehicles as quickly as a device becomes available. The compulsory rule must meet several requirements:

1. It must provide a reasonable time period for the installation of such a device on the automobile population of the County.
2. It must be convenient in its requirements, to the public which must comply with the rule and to the public agencies which must enforce it.
3. It must be practical. The responsibility for this determination cannot be placed upon the public. The motorist must be protected from the sale of "unworkable" equipment.

4. It must be effective and efficient.
5. It must not interfere with the operation of the vehicle. Any interference along these lines will only result in the motorist taking steps to make the device inoperative.

At the present time, there are several devices which are most promising, all of which are either direct-flame afterburners or catalytic afterburners. The development of these devices has been such that it appears that the first effective control device will be installed on an automobile before 1961.

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Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

SALARIES OF LOCAL ENVIRONMENTAL HEALTH PERSONNEL IN 1956

Report of the Committee on Salaries
Conference of Municipal Public Health Engineers

This is the continuation of a Report prepared as a result of a survey of some 3,251 professional positions in environmental sanitation divisions in 371 local health departments. A detailed discussion of how the study was conducted and general data covering all groups of positions was presented in Section I of the Report (Proc. Paper 1282, June, 1957). Sections II, III and IV reported and discussed data on Engineers, Sanitarians and other Sanitation Personnel respectively (Proc. Paper 1685, June, 1958). No attempt will be made here to summarize this data since this was done in the preceeding Sections.

Section V. Conclusions & Recommendations

A. Conclusions

In 1956 the average Sanitary Engineer in a local health department was expected to have had approximately five years' experience and, quite frequently, a master's degree. While his responsibilities to his community his department were mounting, he was paid a salary which not only was generally lower than that of his colleagues in other departments of local government, but in fact 75 per cent of his engineering colleagues in all types of employment were earning salaries higher than his.

In 1956 nearly one out of every four engineering jobs in local health departments was vacant—a considerable increase in vacancies over 1951. Today, two years later, we find that this trend is continuing—more engineers are leaving local health departments. We have good evidence that to a large degree this is due to low salary levels.

Sanitarians in entrance level positions who were required to have a college education were financially about as well off as their classmates, a considerable share of the somewhat higher paying and presumably more important sanitarian positions were vacant. Perhaps this was in part due to the fact that the sanitarian group is still in the growing stage professionally. Two inescapable facts present themselves here: (1) the more responsible sanitarian director jobs were not paying as well as comparable engineering jobs, and

Note: Discussion open until April 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2268 is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. SA 6, 1959.

(2) sanitarian salaries generally did not, unlike engineering salaries, improve substantially with added experience.

These findings raise serious questions concerning the need for professional engineering and sanitarian talent in local health departments. Salaries levels, to some extent, express needs for skilled professional personnel. Here we have two professional groups, one paid substantially below comparable levels in the profession and the other limited in financial rewards which should come with promotional opportunities. One can only ask, therefore, what is the need?

Certainly with the continuing pressures of urbanization, sub-urbanization and population growth, unsolved environmental health problems increasingly present themselves to local health agencies. The newer uses of radiation, growing amounts of air pollution, increasing waste disposal problems (both solid and liquid), toxic substances in our water supply, the new complexities of swimming pool water treatment and the broader aspects of urban planning should have the benefit of consideration professionally trained experts in engineering and sanitation. These are some of the many areas which should win the attention of properly staffed modern local governments in order to protect the citizen. Evidence that the citizen thinks so too is given by the hundreds of daily telephone calls which tell the director of environmental sanitation of his community's felt needs.

What then is the problem? If there is a need for engineers, why the lower salaries? Why is there a need for sanitarians in supervisory positions, without comparable salary levels?

The Committee suggests that one of the bases of the problem is the fact that health department salary structures traditionally are patterned after the relative salary position of the various professional groups which are represented. While it is sound to apply this principle to practitioner level positions where professional competency and skill are major considerations, it is not sound to continue to give primary consideration to professional category status at the higher administrative and supervisory levels. It is at these higher levels that administrative and supervisory competency, and not professional skill, should be primary considerations. Industrial and other organizations have long recognized this principle and continue to use it successfully.

The Committee suggests that there is evidence that undue professionalism in the matter of salary levels is doing irreparable harm to the development and growth of local health services in the United States. All types of professional engineering and sanitarian positions, irrespective of supervisory responsibility, requiring increasing levels of education, experience (and presumably skill) generally do not benefit by comparable salary increases as do professional groups outside of local health departments. Due to the resulting lack, or loss, of competent professional staff and programs, important environmental health services such as housing, air pollution control, industrial hygiene, insect and vector control and others are increasingly being assumed by other units of local government.

The Committee finds that there is a lack of up-to-date salary information available on a continuing basis to administrators in local government who set salaries for environmental health personnel. The hundreds of requests for the Committee's reports suggest this need to the Committee.

B. Recommendations

Since the findings of the Committee are not believed to be confined to environmental health personnel, it is recommended that the Conference of Municipal Public Health Engineers invite the American Public Health Association, the Conference of State Sanitary Engineers and the American Society for Business Management in Public Health and other interested groups to establish and adequately staff a committee on salaries.

In view of the broader implications of the findings of this study it is further recommended that consideration be given by the proposed joint Committee to the need for regular biennial salary studies of public health personnel of all professional categories and at all levels. These studies should relate salaries to job responsibility and requirements and compare salaries with those in similar jobs in organizations outside of public health.

It is further recommended that a special study be conducted in order to determine the degree to which considerations of professional category play a part in setting salaries for management level positions in various types of organizations.

The Committee further recommends that in the event the American Public Health Association is not able to carry out such studies, the Conference explore possibilities to plan such studies jointly with other interested public health groups and obtain the necessary funds for carrying out these recommendations.

Committee on Salaries, Conference of Municipal Health Engineers

Walter A. Lyon, Chairman
William T. Ballard
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John W. Lemon
Eric W. Mood
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ACKNOWLEDGMENTS

A study such as was conducted by the Committee involves a helping hand by a great many persons, particular thanks are due to: Dr. F. Herbert Colwell Dr. D. H. and his staff who helped with the complex task of reducing the data to IBM cards and prepared the many tabulations, Mrs. Adele S. Hebb who helped with the preparation of the questionnaire, Sam Kimble who helped by supplying the addresses of local health departments, the Committee on Publications of the Sanitary Engineering Division ASCE who so willingly published the earlier Sections of this report, the many who helped to comment on, correct and type reports, seal envelopes, draw graphs and most importantly who filled out the questionnaire which served as the source of data for this study.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Department of Conditions of Practice are identified by the symbols (PP). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper number are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 1859 is identified as 1859 (HY7) which indicates that the paper is contained in the seventh issue of the Journal of the Hydraulics Division during 1958.

VOLUME 84 (1958)

NOVEMBER: 1833(HY6), 1834(HY6), 1835(SA6), 1836(ST7), 1837(ST7), 1838(ST7), 1839(ST7), 1840(ST7), 1841(ST7), 1842(SU3), 1843(SU3), 1844(SU3), 1845(SU3), 1846(SU3), 1847(SA6), 1848(SA6), 1849(SA6), 1850(SA6), 1851(SA6), 1852(SA6), 1853(SA6), 1854(ST7), 1855(SA6)[c], 1856(HY6)[c], 1857(ST7)[c], 1858(SU3)[c].

DECEMBER: 1859(HY7), 1860(IR4), 1861(IR4), 1862(IR4), 1863(SM5), 1864(SM5), 1865(ST8), 1866(ST8), 1867(ST8), 1868(PP1), 1869(PP1), 1870(PP1), 1871(PP1), 1872(PP1), 1873(WW5), 1874(WW5), 1875(WW5), 1876(WW5), 1877(CP2), 1878(ST8), 1879(ST8), 1880(HY7)[c], 1881(SM5)[c], 1882(ST8)[c], 1883(PP1)[c], 1884(WW5)[c], 1885(CP2)[c], 1886(PO6), 1887(PO6), 1888(PO6), 1889(PO6), 1890(HY7), 1891(PP1).

VOLUME 85 (1959)

JANUARY: 1892(AT1), 1893(AT1), 1894(EM1), 1895(EM1), 1896(EM1), 1897(EM1), 1898(EM1), 1899(HW1), 1900(HW1), 1901(HY1), 1902(HY1), 1903(HY1), 1904(HY1), 1905(PL1), 1906(PL1), 1907(PL1), 1908(PL1), 1909(ST1), 1910(ST1), 1911(ST1), 1912(ST1), 1913(ST1), 1914(ST1), 1915(ST1), 1916(AT1)[c], 1917(EM1)[c], 1918(HW1)[c], 1919(HY1)[c], 1920(PL1)[c], 1921(SA1)[c], 1922(ST1)[c], 1923(EM1), 1924(HW1), 1925(HW1), 1926(PL1), 1927(HW), 1928(HW1), 1929(SA1), 1930(SA1), 1931(SA1), 1932(SA1).

FEBRUARY: 1933(HY2), 1934(HY2), 1935(HY2), 1936(SM1), 1937(SM1), 1938(ST2), 1939(ST2), 1940(ST2), 1941(ST2), 1942(ST2), 1943(ST2), 1944(ST2), 1945(HY2), 1946(PO1), 1947(PO1), 1948(PO1), 1949(PO1), 1950(HY2)[c], 1951(SM1)[c], 1952(ST2)[c], 1953(PO1)[c], 1954(CO1), 1955(CO1), 1956(CO1), 1957(CO1), 1958(CO1), 1959(CO1).

MARCH: 1960(HY3), 1961(HY3), 1962(HY3), 1963(IR1), 1964(IR1), 1965(IR1), 1966(IR1), 1967(SA2), 1968(SA2), 1969(ST3), 1970(ST3), 1971(ST3), 1972(ST3), 1973(ST3), 1974(ST3), 1975(ST3), 1976(WW1), 1977(WW1), 1978(WW1), 1979(WW1), 1980(WW1), 1981(WW1), 1982(WW1), 1983(WW1), 1984(SA2), 1985(SA2)[c], 1986(IR1)[c], 1987(WW1)[c], 1988(ST3)[c], 1989(HY3)[c].

APRIL: 1990(EM2), 1991(EM2), 1992(EM2), 1993(HW2), 1994(HY4), 1995(HY4), 1996(HY4), 1997(HY4), 1998(SM2), 1999(SM2), 2000(SM2), 2001(SM2), 2002(ST4), 2003(ST4), 2004(ST4), 2005(ST4), 2006(PO2), 2007(HW2)[c], 2008(EM2)[c], 2009(ST4)[c], 2010(SM2)[c], 2011(SM2)[c], 2012(HY4)[c], 2013(PO2)[c].

MAY: 2014(AT2), 2015(AT2), 2016(AT2), 2017(HY5), 2018(HY5), 2019(HY5), 2020(HY5), 2021(HY5), 2022(HY5), 2023(PL2), 2024(PL2), 2025(PL2), 2026(PP1), 2027(PP1), 2028(PP1), 2029(PP1), 2030(SA3), 2031(SA3), 2032(SA3), 2033(SA3), 2034(ST5), 2035(ST5), 2036(ST5), 2037(ST5), 2038(PL2), 2039(PL2), 2040(AT2)[c], 2041(PL2)[c], 2042(PP1)[c], 2043(ST5)[c], 2044(SA3)[c], 2045(HY5)[c], 2046(PP1), 2047(PP1).

JUNE: 2048(CP1), 2049(CP1), 2050(CP1), 2051(CP1), 2052(CP1), 2053(CP1), 2054(CP1), 2055(CP1), 2056(HY6), 2057(HY6), 2058(HY6), 2059(IR2), 2060(IR2), 2061(PO3), 2062(SM3), 2063(SM3), 2064(SM3), 2065(ST6), 2066(WW2), 2067(WW2), 2068(WW2), 2069(WW2), 2070(WW2), 2071(WW2), 2072(CP1)[c], 2073(IR2)[c], 2074(PO3)[c], 2075(ST6)[c], 2076(HY6)[c], 2077(SM3)[c], 2078(WW2)[c].

JULY: 2079(HY7), 2080(HY7), 2081(HY7), 2082(HY7), 2083(HY7), 2084(HY7), 2085(HY7), 2086(SA4), 2087(SA4), 2088(SA4), 2089(SA4), 2090(SA4), 2091(EM3), 2092(EM3), 2093(EM3), 2094(EM3), 2095(EM3), 2096(EM3), 2097(HY7)[c], 2098(SA4)[c], 2099(EM3)[c], 2100(AT3), 2101(AT3), 2102(AT3), 2103(AT3), 2104(AT3), 2105(AT3), 2106(AT3), 2107(AT3), 2108(AT3), 2109(AT3), 2110(AT3), 2111(AT3), 2112(AT3), 2113(AT3), 2114(AT3), 2115(AT3), 2116(AT3), 2117(AT3), 2118(AT3), 2119(AT3), 2120(AT3), 2121(AT3), 2122(AT3), 2123(AT3), 2124(AT3), 2125(AT3).

AUGUST: 2126(HY8), 2127(HY8), 2128(HY8), 2129(HY8), 2130(PO4), 2131(PO4), 2132(PO4), 2133(PO4), 2134(SM4), 2135(SM4), 2136(SM4), 2137(SM4), 2138(HY8)[c], 2139(PO4)[c] 2140(SM4)[c].

SEPTEMBER: 2141(CO2), 2142(CO2), 2143(CO2), 2144(HW3), 2145(HW3), 2146(HW3), 2147(HY9), 2148(HY9), 2149(HY9), 2150(HY9), 2151(IR3), 2152(ST7)[c], 2153(IR3), 2154(IR3), 2155(IR3), 2156(IR3), 2157(IR3), 2158(IR3), 2159(IR3), 2160(IR3), 2161(SA5), 2162(SA5), 2163(ST7), 2164(ST7), 2165(SU1), 2166(SU1), 2167(WW3), 2168(WW3), 2169(WW3), 2170(WW3), 2171(WW3), 2172(WW3), 2173(WW3), 2174(WW3), 2175(WW3), 2176(WW3), 2177(WW3), 2178(CO2)[c], 2179(IR3)[c], 2180(HW3)[c], 2181(SA5)[c], 2182(HY9)[c], 2183(SU1)[c], 2184(WW3)[c], 2185(PP2)[c], 2186(ST7)[c], 2187(PP2), 2188(PP2).

OCTOBER: 2189(AT4), 2190(AT4), 2191(AT4), 2192(AT4), 2193(AT4), 2194(EM4), 2195(EM4), 2196(EM4), 2197(EM4), 2198(EM4), 2199(EM4), 2200(HY10), 2201(HY10), 2202(HY10), 2203(PL3), 2204(PL3), 2205(PL3), 2206(PO5), 2207(PO5), 2208(PO5), 2209(PO5), 2210(SM5), 2211(SM5), 2212(SM5), 2213(SM5), 2214(SM5), 2215(SM5), 2216(SM5), 2217(SM5), 2218(ST8), 2219(ST8), 2220(EM4), 2221(ST8), 2222(ST8), 2223(ST8), 2224(HY10), 2225(HY10), 2226(PO5), 2227(PO5), 2228(PO5), 2229(ST8), 2230(EM4), 2231(EM4), 2232(AT4)[c], 2233(PL3)[c], 2234(EM4)[c], 2235(HY10)[c], 2236(SM5)[c], 2237(ST8)[c], 2238(PO5)[c], 2239(ST8), 2240(PL3).

NOVEMBER: 2241(HY11), 2242(HY11), 2243(HY11), 2244(HY11), 2245(HY11), 2246(SA6), 2247(SA6), 2248(SA6), 2249(SA6), 2250(SA6), 2251(SA6), 2252(SA6), 2253(SA6), 2254(SA6), 2255(SA6), 2256(ST9), 2257(ST9), 2258(ST9), 2259(ST9), 2260(HY11), 2261(ST9)[c], 2262(ST9), 2263(HY11), 2264(ST9), 2265(HY11), 2266(SA6), 2267(SA6), 2268(SA6), 2269(HY11)[c], 2270(ST9).

c. Discussion of several papers, grouped by divisions.

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SA 6

NOVEMBER 1959 — 42 NO. SA 6
VOLUME 85 PART 2

Your attention is invited

NEWS OF THE SANITARY ENGINEERING DIVISION OF ASCE

JOURNAL OF THE SANITARY ENGINEERING DIVISION
PROCEEDINGS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

NEWS

November, 1959

Plan to Attend the Sanitary Engineering Conference in Cincinnati, Ohio
January 6-8, 1960

ANNUAL REPORT OF DIVISION ACTIVITIES
SANITARY ENGINEERING DIVISION
OCTOBER 1958 TO OCTOBER 1959

Executive Committee

Committee Members

The Executive Committee, SED, consisted of Ray E. Lawrence (1960), Chairman, Lewis A. Young (1961), Vice Chairman, John J. Baffa (1962), Richard R. Kennedy (1959) and Arthur D. Caster (1959), Secretary. The contact member from the Board of Directors was N. T. Veatch. H. Loren Thompson has been appointed to succeed Richard R. Kennedy at the expiration of his term on October 21, 1959 and David M. Howells has been appointed to succeed Arthur D. Caster as Secretary. The Executive Committee is deeply appreciative of the fine service which has been rendered by Mr. Kennedy and Mr. Caster during their respective terms of office.

Publications

Through the efforts of our able News Editor, David H. Howells, news coverage of sanitary engineering activities has been steadily increased during the past year. Correspondence with all universities having sanitary engineering programs and with the State health departments is beginning to produce a steady flow of news releases of interest to Division members. The Office of Saline Water, National Academy of Sciences, U. S. Public Health Service, and other state and interstate agencies have included the News Section of the Journal on their mailing lists to receive routine news releases. Headquarters, ASCE, has also been very helpful in providing the News Editor with information concerning sanitary engineering.

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After considerable delay the Manual on Sewage Treatment Plant Design has been issued and the Manual for the Design and Construction of Sanitary and Storm Sewers is in process. The Manual of Practice on Sanitary Landfill which was completed in mimeographed form last year has been published as Manual No. 39.

Cooperation With Other Societies

Close cooperation with the American Sanitary Engineering Intersociety Board is a continuing and important activity of the SED. Our representatives to this Board are Thomas R. Camp who has been reappointed to a three year term, Richard Hazen and Blucher A. Poole. Mr. Camp serves as Chairman of the ASEIB.

During the year the Joint Committee for the Advancement of Sanitary Engineering was dissolved and the functions of the Joint Committee were taken over by the ASEIB. Involved primarily were two active sub-committees of the Joint Committee, both of which are cooperating with the U. S. Public Health Service on projects dealing with recruitment and advancement of sanitary engineering.

The first roster of the American Academy of Sanitary Engineers has been published and it includes approximately 1000 members. Examinations for certification were held recently for 39 candidates in 14 locations from Seattle, Washington to Gainesville, Florida.

Standards

The Executive Committee has under active study the desirability of organizing a Sanitary Engineering Division Committee on Standards. The matter will be considered in detail at the time of the next Executive Committee meeting to be held in Cincinnati on January 5, 1960 with the view to taking definite action.

Committee on Technical Procedure

Ray Lawrence represented SED at the meeting of the Committee on Technical Procedure which was held in Chicago on April 17, 1959. The meeting this year was attended by a much smaller group than the former Conferences on Technical Procedure. Much of the discussion was directed to ways and means of bringing about closer liaison between the Technical Divisions and the Board of Directors of the Society.

Water Resources Coordinating Committee

Richard Kennedy has served as the representative of the Executive Committee, SED, on the Water Resources Coordinating Committee. This is a Committee of the Society which was established to review the programs of the several Technical Committees in carrying out their obligations to cover the field of Water Resources, particularly in the areas in which the coverage was found to be inadequate.

The Water Resources Coordinating Committee, under the chairmanship of Finlay B. Laverty, met in Los Angeles on March 14-15 and again in Chicago on April 16. The Chicago meeting was held jointly with the Committee on Division Activities and was attended by Ray Lawrence as representative of the Executive Committee.

As a result of these meetings the SED has been assigned additional responsibilities in the area of Water Resources and these in turn have been assigned by the Executive Committee to the SED Committee on Water Supply Engineering.

National Conference SED

The first Sanitary Engineering Division Conference on Water, Air and Land Pollution will be held in Cincinnati on January 6, 7, and 8, 1960. Arthur D. Caster, Secretary Executive Committee, is acting as General Chairman in charge of the Conference. He is being assisted by Ray Raneri and other members of the Cincinnati Section. Secretary Arthur S. Fleming, Department of Health, Education and Welfare, will speak at the dinner meeting on January 7 on the subject "What Can Our Culture Afford." Senator Kerr of Oklahoma will give a talk at the opening session on January 6, on "The National Policies on Resources Control."

Committee on Publications

Committee Members

Israel W. Santry, Jr.* Chairman, John B. Nesbitt,* Vice Chairman, William W. Aultman,* William A. Cawley, William E. Dobbins, Julian B. Fleming, Jack H. Fooks, Earnest F. Gloyna, Werner N. Grune, David H. Howells, Warren J. Kaufman, John E. Kiker, Jr.* Lindon J. Murphy, Richard Sage Murphy, Roy E. Ramseier.*

Accomplishments

The Publications Committee, SED, met at Cleveland, Ohio on May 3, 1959 to consider the following items of business.

1. To discuss ways and means of expediting the handling of papers.
2. To discuss recruitment of new personnel for reviewing papers.
3. To review grading standards used in SED Journal and Transactions.
4. To assign areas of review activity within the Sanitary Engineering field to the reviewers.
5. To start the preparation of the Annual Report to the Executive Committee.
6. To start the program of the sub-committee for the development of securing good papers for publication and to discuss other means that might be available for the promotion of technical papers.
7. To discuss any matter arising out of the above or other matters brought by the committee members to the meeting.

Committee on the Rudolph Hering Medal

Committee Members

William W. Aultman, Chairman; Earnest Boyce; Nelson L. Nemerow.

*Members of 1958-1959 Committee Control Group.

Accomplishments

This year the Committee recommended the award to Donald J. O'Connor, Jr., M. ASCE, and William E. Dobbins, M. ASCE, for their paper, "Mechanism of Reaeration in Natural Streams," Transactions Paper No. 2934.

Committee on Sanitary Engineering Research

Committee Members

N. L. Nemerow, Chairman - Industrial Wastes; W. T. Ingram - Air Pollution; E. R. Hendrickson - Air Pollution; R. Stone - Refuse; R. H. Bogan - Sewage; C. H. Hull - Water; M. A. Churchill - Stream Pollution; H. A. Faber - Public Health.

Accomplishments During Year

1. Published the following Research Reports in Journal:

   A. No. 21 Sanitary Land Fill Tests Investigating Refuse Volume Reduction and Other Phenomena—Seattle, Washington (Refuse Section)
   No. 22 An Evaluation of Two Recent Industrial Waste Treatment Processes (Industrial Wastes Section)
   No. 23 Sludge Treatment and Disposal by the Zimmerman Process (Sewage Section)

   B. To be published

   No. 24 Education Solid Wastes Disposal Survey (Refuse)
   No. 25 Seminar on Sanitary Engineering Research (General)
   No. 26 Refuse Volume Reduction in a Sanitary Land Fill (Refuse)

2. A resolution was presented to the Executive Committee for Federal financial support of an additional $750,000 for sanitary engineering research. This resolution after Executive Committee approval was forwarded to the Society Research Committee.
3. An attempt is being made to secure for our research committee a seat on the research proposal review on the Study Section of the National Institute of Health. This should provide closer coordination between sponsored sanitary engineering research and the ideas and interests of our Division.

Committee on Sessions Programs

Committee Members

Conrad P. Straub, Chairman; Vinton W. Bacon; C. Richard Walter; Kenneth I. Mullen; Harry H. Moseley; Stanley E. Kappe; Walter E. Blessey.

Accomplishments

The Committee consists of three members at large, serving staggered three year terms, and three members representing geographic areas of the next three national ASCE conventions, each appointed for the year ending with

the close of the convention in his area. Conrad P. Straub, Chairman for the year 1958-59, Vinton W. Bacon who will serve as Chairman for the year 1959-60, and C. Richard Walter are the Committee Control Group. Kenneth I. Mullen, Harry H. Mosely, Stanley E. Kappe and Walter E. Blessey are the Area Representatives, and Richard R. Kennedy is Contact Member from Division Executive Committee.

Every effort is made to select program subjects of a quality to warrant publication in the SED Journal. To this end close cooperation is maintained with the SED Publications Committee, so that authors might be engaged as speakers, and speakers as authors.

Committee on Atmospheric Pollution

Committee Members

Control Group: William T. Ingram, Chairman; Albert F. Bush; William S. Foster; Alvin F. Meyer, Jr.; Frank Tetzlaff.

Advisors: Richard E. Hatchard; August T. Rossano, Jr.

Task Force Assignments

Introduction: William S. Foster, Chairman.

I. The Status of Air Sanitation Activity, Sections A, B, C and D: Richard E. Hatchard, Chairman.

II. Discussion of Air Sanitation Engineering, Sections A, B, and C: Harry E. Seifert, Chairman.

II. Discussion of Air Sanitation Engineering, Section D: August T. Rossano, Jr., Chairman.

II. Discussion of Air Sanitation Engineering, Section E: Frank Butrico, Chairman.

III. Discussion of Education and Training, Sections A and B: Ellwood R. Hendrickson, Chairman.

IV. Discussion of Research Activities on Atmospheric Pollution and Its Control, Sections A, B, C, D and E: William T. Ingram, Chairman.

V. Discussion of Activities of Other Branches of Engineering Societies and Co-Related Associations:

VI. Radioactive Pollutants, Sections A, B, C, D and E: James G. Terrill, R., Chairman.

VII. Discussion of Standards and Guides to Design Practice in Engineering Management of the Air Resource, Sections A, B, C, D and E: Albert F. Bush, Chairman.

VIII. Discussion of Standards and Guides to Design Practice in Engineering Management of the Air Resource, Sections A, B, C, D and E: Albert F. Bush, Chairman.

VIII. A Proposal Setting Forth the Opportunity for Sanitary Engineers in an Important Area of Environmental Control: William T. Ingram, Chairman.

Accomplishments, 1958-1959

Committee activity during the year has been a matter of working with task force assignments. Target dates originally assigned have lapsed largely because all persons involved have been overtimed with work loads of their positions.

New Activities

In view of the present policy of the Society with respect to the publication of Manuals of Practice the Committee on Atmospheric Pollution will meet in January 1960 at Cincinnati for purposes of re-orientation of its program.

Committee on Industrial Waste Practices

Committee Members

S. Leary Jones, Chairman; Edward F. Eldridge; Frank P. Coughlan; David A. Robertson, Jr.; Paul D. Haney; Roy F. Weston, David P. Smallhorst.

Objectives

To collect and compile existing information regarding present practices of utilization, recovery and treatment of specific industrial wastes, and on the basis of this information to prepare or assist in the preparation of reports, papers, memos, normographs and/or manuals which will act as guides to engineers and industrialists in the solution of waste disposal problems.

To maintain a running inventory of projects involving industrial waste practices and report the significant practices to the editorial staff of SED news.

To observe and note voids in the information regarding industrial waste practices and suggest appropriate studies to the SED.

Accomplishments During Year

The committee was appointed in January, 1959, and spent the time getting organized. No papers have been prepared or submitted as yet. Notes on a suggested program were submitted to the Executive Committee in April.

Committee on Preparation of a Manual of Practice on Incineration of Municipal Refuse

Committee Members

M. H. Klegerman, Chairman; F. R. Bowerman; Samuel M. Clarke; Roy H. Ritter; Casimir A. Rogus.

Accomplishments

The Committee has developed a substantial amount of background material through the activities of Committee and Task Force members and several chapters have actually been completed in preliminary draft. However, the Committee finds itself in the position of questioning the general idea of establishing "standards" for Municipal incinerator design and there is considerable skepticism on the part of some Committee members as to the usefulness of such a Manual.

New Activities

The Board of Directors, ASCE, took action during the Cleveland Meeting which states that:

"Manuals shall be limited to non-technical material of use and interest to all engineers such as review of salaries, form of engineering contracts, employment conditions, education subjects, and the like."

In view of this action the Committee on Preparation of a Manual of Practice on Incineration of Municipal Refuse has scheduled a meeting at the time of the SED Conference in Cincinnati in January 1960 for purposes of re-orientation.

Committee on Public Health Activities

Committee Members

W. W. Towne, Chairman; E. C. Jensen; B. B. Berger; D. F. Metzler; C. L. Senn.

Accomplishments

The April, 1958 and June, 1958 issues of the SED Journal contained the comprehensive study of the Committee on Public Health Activities on the impact of urban growth on suburban areas. During the past year the Committee has continued its study of this timely subject. The Committee has also explored other areas of activity.

New Activities

The Committee is considering the possibility of developing a report which would point out the impact of Public Health problems upon the Engineering Profession as a whole. This is brought about by the observations of some of the Committee members that there is a lack of understanding and appreciation within certain government agencies on the relationship of water management and utilization practices to mosquito breeding. There is also a feeling that there are many other cases where a better understanding of Public Health problems would be highly desirable.

Committee on Sanitary Engineering Aspects of Nuclear Energy

Committee Members

Earnest F. Cloyna, Chairman; J. G. Terrill, Jr.; Warren Kaufman; E. C. Tsivoglou; Ben Ewing; Sherwood Davies; Arthur Gorman. In line with past policy, the chairman passes his duties to the next person on the list and vacates a position on the committee at the end of the year. The Committee Chairman for 1959-60 should be J. G. Terrill, Jr., according to the rotation scheme adopted several years ago.

Accomplishments

The efforts of the Committee have been directed towards writing a paper for ASCE Proceedings. The paper will also be presented at the fall meeting in Washington, D. C.

Committee on Sewerage and Sewage Treatment

Committee Members

Kerwin L. Mick, Chairman; Francis R. Bowerman; Gail P. Edwards; Wm. F. Garber; Paul D. Haney; B. Benas; Dean M. Taylor.

Committee on Water Supply Engineering

Committee Members

Robert D. Mitchell, Chairman; G. E. Arnold; Paul Haney; Richard Hazen; John A. Logan.

Purpose

To study, stimulate or sponsor research and report on the problems connected with providing an adequate supply of water for community needs; methods of integrating these needs into regional, area or local planning; methods of control, treatment and construction to develop, protect or reclaim water for full beneficial utilization particularly as they relate to water for domestic and industrial use, recreation and wild life preservation; correlate work done in the field of sanitary engineering with that being done in other fields of engineering and science. The Committee by means of task committees or otherwise shall act as a clearing house for the coordination and dissemination of information on these subjects at meetings and conferences.

Accomplishments

At the Executive Committee meeting held October 14 and 15, 1958 in New York, it was decided to rewrite the purpose of the Water Supply Engineering Committee's operations and form a new control group for the work. The activities of the Water Supply Committee during the 1958-59 year were aimed toward the accomplishment of the new directive given at the October meeting. During the year a new control group was formed consisting of Robert D. Mitchell, Chairman, Richard Hazen, G. E. Arnold, Paul D. Haney and John A. Logan. Previously appointed members of the committee were consulted concerning their interest in continuing with the committee and to obtain their comments on the change in the committee activities.

At the Chicago meeting of the Executive Committee, held on April 18, 1959, a statement of purpose for the Water Supply Engineering Committee was adopted. Advice was received by letter from Richard R. Kennedy dated June 25, 1959, that the Chairman of the Water Resources Coordinating Committee had approved the statement of purpose prepared for the Water Supply Engineering Committee, so that the way appears cleared for the revised operations of the committee to proceed.

In the meantime, meetings and correspondence with the various members of the control committee resulted in the decision to set up committees to carry out task committee type of investigations in three different fields of operation. There are as follows:

1. Task Committee on Water Hammer
2. Task Committee on Cost Benefit Studies of Public Water Supply
3. Task Committee on Instrumentation

Did You Know That

Richard F. Poston is being assigned by the Public Health Service to the U. S. Study Commission, Southeast River Basins in Atlanta, Georgia, as sanitary engineering consultant on the Commission staff. Mr. Poston was formerly Regional Program Director, Water Supply and Pollution Control in the San Francisco Regional Office of the Public Health Service.

Paul W. Reed has joined the staff of the U. S. Study Commission--Texas, Houston, Texas, on detail from the Public Health Service. Mr. Reed is a former Editor of this Newsletter, and recently has been Chief of Operations for the Construction Grants Program in the Public Health Service pollution control work.

Lawrence Clark of Birmingham, Alabama has been awarded a Clow Foundation Fellowship to pursue graduate studies in Sanitary Engineering at the Alabama Polytechnic Institute, Auburn, Alabama, beginning with the Fall 1959 quarter. This fellowship, established by James B. Clow & Sons, Inc., has as its main purpose the encouragement of graduate study in Sanitary Engineering so as to increase the engineering skills and knowledges involved in planning and designing municipal water and sewage systems.

* * *

SANITARY ENGINEERING RESEARCH

A Ten-Year Test on High Rate Filtration

John R. Baylis, Engineering of Water Purification, City of Chicago, recently reported on a ten-year test on high rate filtration at the South District Filtration Plant. The conclusions of this long time experiment are reported below. The entire report was published in the June 1959 issue of Pure Water, a monthly publication of the Department of Water and Sewers.

Conclusions

1. In filtration plants where a coagulant aid may be used during periods of weak coagulation, sand filters will produce a satisfactory quality of water operating at a rate of 5 gpm per sq. ft. of filter surface.
2. The friction loss through sand beds increases so rapidly, as the rate increases above about 3 gpm, that filtration plants should not be designed for a 5-gallon rate, except for occasional use for short periods such as a few hours daily during peak usage of water in the summer months, or during dry periods.
3. The data indicate that filters could be designed capable of being operated at a 4-gallon rate, although continuous operation at a 4-gallon rate is not recommended.
4. The experiments show that doubling the filtration rate decreases the length of filter run 45 to 50 per cent from the runs at the 2-gallon rate. If the runs at the 2-gallon rate are 24 hours, the 4-gallon rate filters will have runs 12 to 14 hours. This means that more water is filtered between washes on filters operated at 4-gallon rates that filters operated at a 2-gallon rate.

5. The greater performance for the high-rate filters indicates that the coagulated material penetrates deeper into the filter beds. If so, high-rate filters likely would pass flocculated matter at a lower loss of head than the 2-gallon rate filters.
6. Generally the coagulated material at the South District Plant is so strengthened with micro-organisms that there is no need for the use of a coagulation strengthening agent, such as acid-treated sodium silicate.
7. As shown by data from the experimental plant, the Lake Michigan water at Chicago would require the occasional use of a coagulant strengthening agent at the 2-gallon rate. Many waters throughout the country have periods of weak coagulation often enough to warrant the use of a strengthening agent.
8. The fact that coagulant aids are used in so few filtration plants should call for a renewed effort on the part of water purification chemists to improve the quality of filtered water. Investigation may reveal that much of the lessened capacity of water distribution pipes, generally attributed to rust tubercles, is actually caused from the coagulated material that passes through filters adhering to the wall of the pipe.
9. The cotton plug filter, relied on as our main water quality testing device, should be in more common use.
10. The cotton plug filter is slow in giving the operator the information desired. Another method of testing, just in early experimentation, offers some hope of producing a test whereby the operator may tell within a few minutes if the water is up to standard quality. This is the membrane filter, used for bacteriological work. It may prove to be of considerable value in quickly estimating the coagulated material passing filters.

Effect of Fluoride on Corrosion

From time to time there have appeared statements that fluoridation increases the corrosive properties of water, even in the very low concentrations used for the purpose of reducing the incidence of dental caries.

Joseph A. McCarthy, Chief, Lawrence Experiment Station, Massachusetts Department of Public Health recently reported that the effect of fluorides has been investigated by experiments with water from the public supply at North Andover. This supply is a "soft" surface water, typical of many of the supplies in Massachusetts. This water is known to be corrosive, and alkaline treatment was given to the water at the pumping station: for the past year or two the pH of the water leaving the station has averaged about 8.4. At the point of collection the pH of the water has changed considerably, and on the days of collection of the water used in the experiments the pH was 6.7.

Analyses of the water for iron, copper, and lead at intervals up to 46 days after strips of these metals were placed in containers of the water with and without 1 ppm of fluoride, indicated that the amount and rate of solution of all three metals were identical at any given time in both containers of each pair, and that the added fluoride had no effect on the corrosion of these common household metals.

Space Studies At SEC

Initial studies into the water conservation and waste disposal problems associated with space craft have been conducted by the Taft Sanitary

Engineering Center in conjunction with Dr. L. G. Rich of the Illinois Institute of Technology. The first paper on this subject, "A Balanced Ecological System for Space Travel", will appear in the Proceedings of the Sanitary Engineering Division, ASCE. A second paper will be presented in New York at the annual meeting of the American Astronautical Association in January, 1960. These investigations suggest an interesting and challenging area of sanitary engineering research.

Water Treatment Studies

The U. S. Public Health Service, the South Carolina Public Health Department, and the Board of Public Works of Gaffney, S. C. have started a joint study of filtration rates at the 3 mgd Gaffney water treatment plant. The Engineering Section of the Public Health Service Sanitary Engineering Center has installed instruments at the plant to record the turbidity of filter influent and effluents from the anthrafilt filters as the rates are changed from 1 on up to 6 gpm/sq. ft. Coliform and streptococci counts are being made also during a short period of no pre-chlorination. If continued over several seasons, this study should help to demonstrate if a small sized treatment plant can constantly produce a satisfactory water at various filtration rates.

Small Water Pasteurizer Developed at SEC

A continuous flow pasteurizer for small water treatment systems has been developed at the Taft Sanitary Engineering Center, and is now undergoing field trials. The pilot unit produces drinking water which meets Public Health Service bacteriological standards in sufficient quantity to supply a family of five (90,000 gallons annually) at a treatment cost of $1.00 per 1,000 gallons. Most of the heat supplied to the water by electricity is recovered through the use of a simple heat exchanger. Copies of the report on construction and performance may be obtained from the Engineering Section, WS&WP Research Branch, at the Center.

* * *

SANITARY ENGINEERING EDUCATION

COSTEP Employs Student Engineers

One hundred medical, dental, engineering, science, nurse and veterinary students from 53 four-year professional schools served on temporary duty with the U. S. Public Health Service as members of the Service's Commissioned Reserve during this past summer.

The students constitute the latest groups to receive special training under the Service's Commissioned Officer Student Training and Extern Program (COSTEP). Assignments under COSTEP are open each year to medical, dental, engineering, science, nurse and veterinary students who complete either their second or third year of professional education on or before July 1.

Students selected for COSTEP received commissions in grades equivalent to those held by officers in the Armed Forces. They are then placed on active duty for a period not to exceed 120 days.

The purpose of COSTEP is fourfold: (1) to stimulate the interest of promising students in careers in the Public Health Service, principal health agency of the Federal Government; (2) to enable students to further their professional knowledge while gainfully employed; (3) to give students an opportunity to increase their understanding of and interest in the functions of government and independent public health agencies; (4) to provide the Service with competent help during the vacation months.

The largest number of students under COSTEP are employed by the Service during the summer months. However, the program is open the year around, and students attending schools operating on the quarter system can apply throughout the year.

Further information about the COSTEP program can be obtained from the Chief, Division of Personnel, U. S. Public Health Service, Washington 25, D. C.

Grants for Sanitary Engineering Research Facilities

Surgeon General Leroy Burney, Public Health Service, recently announced approval of grants to help build and equip sanitary engineering research facilities at the California Institute of Technology in Pasadena, California and Ohio State University in Columbus, Ohio. California Institute of Technology received a grant of $39,900 and Ohio State received a grant of $5,000.

These grants are being made under the authorization of the contingent resolution for fiscal year 1960, which was passed by Congress on June 30, 1959. They are the first to be awarded under the three-year program extension authorized by the 85th Congress during 1958. The extended program, like the initial program established in 1956, is authorized at $30 million annually.

Administered at the National Institutes of Health, Bethesda, Maryland, the health research facilities construction program is designed to expand and improve the nation's facilities for medical and related health research. Grants are made to both public and nonprofit hospitals, medical and dental schools, schools of public health, and other research institutions, and are awarded on a matching fund basis.

Under the initial three-year program, 493 health research facilities construction grants were awarded to 247 institutions throughout the United States and in Hawaii.

* * *

WATER SUPPLY AND WATER POLLUTION CONTROL

Mr. Arthur S. Fleming, Secretary of Health, Education, and Welfare issued a notice to the City of Saint Joseph and 18 meat-packing and other industrial establishments to cease discharging untreated wastes into the Missouri River on August 13, 1959. Action was based on the findings and recommendations of the hearing board appointed under provision of the Federal Water Pollution Control Act of 1956.

The cease and desist notice to the city and the 18 industrial plants directs that they complete and place into operation by June 1, 1963, "proper, adequate, and effective municipal and industrial sewage and waste collection, treatment, and disposal facilities."

This is the second time the Secretary's authority has been used to direct specific pollution control action by a municipality and its associated industries under the enforcement provisions of the 1956 act.

As in the first action, which involved Sioux City, Iowa, and 10 meat-processing establishments in that city, the cease and desist notice to the City of Saint Joseph and the 18 industrial establishments followed a unanimous recommendation of the hearing board.

The hearing board found that pollution of the Missouri caused by the discharge of untreated wastes from Saint Joseph and its industries constitutes a health hazard and seriously interferes with use of the stream in Kansas as a source of public water supply, and for navigation, fishing, boating, and recreation.

The board found that effective, feasible, and reasonable methods for the control and treatment of sewage and industrial wastes were available to the City of Saint Joseph and the associated industries, and that if these wastes were effectively controlled and treated Missouri River pollution would be "substantially abated and its waters would be substantially restored and improved."

Under the enforcement provisions of the Federal Water Pollution Control Act, a hearing board is appointed by the Secretary to examine a pollution problem only if a formal conference called by the Surgeon General of the Public Health Service does not result in effective abatement actions. Such a conference was held at Saint Joseph on June 11, 1957.

As part of the overall program to restore the Missouri River system to safe and usable condition for a variety of purposes, conferences also have been held at Kansas City, Missouri; Omaha, Nebraska; and Beatrice, Nebraska.

As a result of agreements reached at these conferences, a number of steps have been taken to control water pollution without further application of enforcement procedures.

For example:

1. Sewage-treatment plants have been completed or are under construction in 6 cities in Nebraska—Hastings, Milford, Beatrice, Crete, Seward, and Wilber—which formerly discharged raw sewage into the Big Blue River.
2. On the Missouri River, Bellevue and Nebraska City, Nebraska, are planning construction projects. Omaha is enlarging one sewage-treatment plant; is preparing to let contracts for two major interceptor sewers; and is planning to bond-issue election of $10,000,000 for construction of a new treatment plant.
3. Further south along the Missouri, Kansas City, Kansas, is spending $3,700,000 for interceptor sewers and sites for sewage-treatment facilities; Kansas City, Missouri, has completed preliminary engineering studies; and Independence, Missouri, has held a successful bond-issue election to finance a new sewage-treatment plant.

How to Get Sewers in St. Louis

The Metropolitan St. Louis Sewer District has issued a brochure detailing steps necessary for citizens to take in obtaining sanitary and storm sewers. Entitled the "Subdistrict Development Method", the attractive brochure provides detailed information on the governmental procedures necessary to get sewers.

The various steps required are fully and simply explained under the following headings: 1. Petition, 2. Engineering Study, 3. Public Hearings, 4. Resolution of Necessity, 5. Decision of Public Interest, 6. Full Steam Ahead, 7. Advertising for Bids and Beginning Construction, 8. Accepting Project and Assessing Costs, 9. Paying the Special Tax Bills.

Further information concerning the pamphlet, its development and use, may be obtained from William Q. Kehr, Executive Director, Metropolitan St. Louis Sewer District, 901 Washington Avenue, St. Louis 1, Missouri.

Low-Flow in Alabama Streams Studied

A comprehensive report on the low-flow characteristics of streams in Alabama has recently been completed for the Alabama Water Improvement Commission by the U. S. Geological Survey.

In May 1957, the Commission requested the U. S. Geological Survey to "study and investigate the magnitude and frequency of low flows of the streams of Alabama" with a view toward providing the Commission with low-flow information that would be useful in the investigation, prevention, and control of stream pollution. Particularly desired was a convenient method for appraising the normal low-water capability of Alabama streams to dilute pollutional wastes.

The information presented is sufficient to appraise the normal low-water capability of 191 Alabama streams to dilute wastes at 254 specific sites throughout the State and, through interpolation, at many points along the main stems of 12 of the major streams. As secondary objectives, the report (1) provides useful information for the selection of surface-water supplies for domestic or industrial use; (2) provides information which may at some future time prove useful in connection with legal problems of allocating water supplies; (3) provides a low-flow parameter of definite frequency for the same historical period for practically all gaged streams in the State, thus making possible a direct comparison of the low-flow characteristics of those streams on an areal basis; and (4) provides flow-duration data adjusted to the same historical period for gaged streams. In addition to their conventional uses, these flow-duration tables provide a convenient basis for graphical relations of discharge which make it possible to express low-flow experiences of one stream in terms of another.

The methods used in developing the report do not make possible reliable estimates of the magnitude and frequency of low flows for totally ungaged streams. However, methods are available whereby reliable estimates can be made with only a limited amount of information on stream discharge.

Further information concerning the report and its availability may be obtained from Arthur N. Beck, Technical Secretary, Water Improvement Commission, Alabama State Department of Health, Montgomery 4, Alabama.

7th National Watershed Congress to Nation's Capitol

Representatives of the more than 25 farm, business, conservation, and industrial organizations that sponsor the annual National Watershed Congress have selected Washington, D. C. for the next meeting. The Congress, which is open to all persons interested in the development of upstream tributary areas as a means of stabilizing water flows and combatting floods and soil erosion, will be held in the Statler-Hilton Hotel on April 18-20, 1960.

Manhattan College Schedules Third Waste Conference

On April 20, 21, and 22, 1960, Manhattan College will present its Third Biological Waste Treatment Conference. The object of this conference will be to present advances in aerobic treatment since Manhattan's 1955 conference on the same topic. The symposia planned will cover the Theory of Bio-oxidation, Aeration and Oxygen Transfer, and Treatment and Process Applications.

Further information may be obtained from W. Wesley Eckenfelder, Associate Professor of Sanitary Engineering, Manhattan College, Riverdale, New York 71, New York.

PHS Investigates Ground Water Pollution

The Public Health Service recently announced it will investigate possible contamination of underground water supplies near the U. S. Army Chemical Corps Rocky Mountain Arsenal outside Denver.

Dr. Graham Walton, sanitary engineer at the PHS Sanitary Engineering Center, Cincinnati, will conduct the survey.

The survey will determine whether there is necessity for a more extensive study of pollutants in underground and surface waters on the Arsenal property and outside the Chemical Corps installation. The study was requested by the Governor of Colorado, Congressman Byron L. Johnson and Colorado Department of Public Health.

Senate Water Resources Committee to Hold Hearings

The new Senate Select Committee on National Water Resources will conduct a series of 19 public field hearings in all parts of the U. S. during the period Oct. 7-Dec. 8.

The new Committee was created earlier this year for the purpose of studying: "(A) the character and extent of water resource projects that will be needed to be in operation between the present time and 1980 and 2000 in order to supply the water use requirements of population, agriculture, and industry, including but not limited to navigation development and hydroelectric power generation, and with appropriate provision for flood control, and the realization of recreational and wildlife values; and (B) the character of legislation that may encourage the adoption of new technical methods and improved process for increasing the usefulness of available water resources, including but not limited to weather modification, evaporation and evapo-transpiration reduction, desalination of saline and brackish waters, seepage control, waste-water salvage, and the application of nuclear energy."

Federal governmental agencies concerned with water resources already have been asked to prepare appropriate reports.

The Committee is to transmit results of the study and recommendations to the Senate by Jan. 31, 1961. It is authorized to contract with organizations, schools and other institutions and individuals for special studies. Initial funds for the study amount to $175,000.

Senator Robert S. Kerr (Okla.) serves as chairman of the committee and Senator Thomas H. Kuchel (Calif.) is vice-chairman. Others on the 17 man committee are: Senators Chavez (N.M.), Ellender (La.), Magnuson (Wash.),

Anderson (N.M.), Jackson (Wash.), Engle (Calif.), Hart (Mich.), McGee (Wyo.), Moss (Utah), Murray (Mont.), Young (N.D.), Schoeppel (Kans.), Case (S.D.), Martin (Iowa), and Scott (Pa.).

The following is the list of hearing dates and places.

Date	Location	Date	Location
Oct. 7	Bismarck, N. D.	Nov. 18	Topeka, Kans.
Oct. 8	Laramie, Wyo.	Nov. 19	Des Moines, Iowa
Oct. 9	Billings, Mont.	Nov. 20	Santa Fe, N. M.
Oct. 12	Missoula, Mont.	Nov. 23	Salt Lake City, Utah
Oct. 13	Boise, Idaho		
Oct. 15	Sacramento, Calif.	Nov. 30	Alexandria, La.
Oct. 16	Los Angeles, Calif.	Dec. 2	Columbia, S. C.
Oct. 26-7	South Dakota	Dec. 3	Jacksonville, Fla.
Oct. 29	Detroit, Mich.	Dec. 7	Augusta, Maine
Oct. 30	Philadelphia, Pa.	Dec. 8	Boston, Mass.

Interior and Army Departments Clarify Reservoir Recreation Stand

The Interior and Army Departments have joined in a policy statement which is designed to clarify the positions of the two agencies on land acquisition at federal reservoirs for recreation and fish and wildlife purposes. The policy declaration focuses attention on the consideration that must be given recreation and fish and wildlife resources early in the planning of reservoir projects. The two agencies now are expected to modify established procedures so that each can cooperate fully in the new approach.

Montana Presses Sewage Treatment Plant Construction

The Montana State Board of Health recently took positive action to have several cities comply with its orders to present plans for satisfactory sewage treatment. The Board requested officials of one city to prepare a satisfactory plan prior to its next meeting and also directed its staff to prepare a court order should the city fail to present a suitable plan of action. In addition, it directed the State Board of Health staff not to authorize or approve any sewer extensions.

For another city, the Board directed its staff to approve sewer extensions only after bonds for sewage treatment and disinfection have been voted, and the city has agreed to have the treatment plant in operation.

Eleven other cities were requested to submit a statement of plans for accomplishing sewage treatment at the next Board meeting. These thirteen cities are the only ones remaining of a total of sixty that were warned in 1952 that sewage treatment must be under way by July 1, 1959.

* * *

AIR POLLUTION

Air Pollution Problem Gets More Attention

In an article entitled "Our Polluted Inheritance," the August 1 issue of SCIENCE NEW LETTER devoted considerable attention to the problem of air pollution. Excerpts from the article follow:

> "Pollution has been handmaiden to our national program. It costs America an estimated $7.5 billion a year. This amounts to $42 for each man, woman and child, although some estimates run as high as $65 per person per year. (See Civil Engineering, August 1959).
>
> "This economic tax, in many ways, is paid by the average citizen, but he may not realize it.
>
> "In Cincinnati, Ohio, a smokestack spewed hydrogen sulfides into a rainstorm. This gas rose into the slow-moving cloud overhead. Early the next morning, the cloud passed over Reading, Ohio, and some early risers watched with dismay as their houses coated with paint containing lead turned black. Houses in an area 100 feet wide and half a mile long had to be repainted.
>
> "In Los Angeles, a hen laid a green egg. She tried again. Same result. After many tries to lay a white egg, the hen gave up and quit. The owner later learned that a smog chemical had combined with the moist eggshells to make the green hue.
>
> "In Washington, D. C., a woman took down her soiled window curtains to wash them in the bathtub. She added a mild liquid soap, dumped in the curtains and watched with horror as the material disintegrated. An air pollutant had settled on the material and attacked it, needing only a good 'bath' to finish the job.
>
> "Those examples show how air pollution taxes the American wallet. There are other taxes too. We pay a tax in health. Respiratory illnesses jump when pollution closes in on a city or town. Persons of frail health have collapsed under this added hazard. Many have died . . . Certain chemicals found in air pollution have been shown to cause cancer in mice. Will they likewise cause cancer in man?
>
> "Already our population has grown rapidly past the 177,000,000 mark. Air pollution is also increasing rapidly. Scientists are finding out what air pollution is, and engineers are working on ways to control it. But without a rising tide of public support, it appears our best efforts can be described only as 'inadequate.' We will be saddled with a polluted inheritance."

The NEWS LETTER, published by Science Service, Inc., of Washington, D. C., then pointed out that many people consider that "smoke means jobs" but added the comment: "But the fact that smoke goes with prosperity is not so. There are too many good smoke-catchers commercially available."

Citing the automobile as the biggest single source of widespread pollution, the article discussed problems of cities controlling the problem. "Many experts say these cities are merely holding their own at present. In the light of expected industrial expansion to meet our growing population needs, they will lose ground in fighting the pollution menace, unless they can get strong local laws . . . The Federal Government can take only limited action. Air pollution is peculiarly a local problem."

New Task Group to Cooperate on Auto Exhaust Research

The first meeting of a Technical Task Group on Automobile Exhaust Research was held in Los Angeles on July 16. The new group will serve to provide technical liaison among a number of agencies actively engaged in such research—through the exchange of technical information, the promotion of comparability of research procedures, joint planning and voluntary cooperation, and voluntary coordination in research effort. In addition to the Public Health Service, which is sponsoring the group, the membership includes representatives of the U. S. Bureau of Mines, the Los Angeles County Air Pollution Control District, the University of California at Riverside, the Air Pollution Foundation, and the oil and automotive industries. Other organizations may be invited to participate as developments in the field dictate.

General Motors to Finance New Cancer-Auto Exhaust Study

General Motors is considering financing a broad study of the possible link between automobile exhaust fumes and lung cancer. The proposed cancer study, the first such project by an individual automobile manufacturer, would be conducted by the Sloan-Kettering Institute for Cancer Research.

Influential Journal to Canvass Mining Industry on Air Pollution

The July issue of Engineering and Mining Journal featured on its cover "Air Pollution—Industry's Challenge." This is the title of a nine-page article on the subject by James W. Franklin, Associate Editor, one of the most comprehensive to appear so far in any periodical. In an editorial in the same issue, this trade journal announces its intention to canvass the mining industry "to acquire more of the story." The results of this survey will be published in a later issue.

Air Pollution Courses

Rutgers University is again offering two courses in air pollution for the academic year 1959-1960. For the first term "Principles of Air Pollution Control" will be presented on Fridays from 2 to 5.

For the second term commencing February 5, 1960, "Air Sampling and Analysis" will be presented on Fridays from 1 to 5. Additional information may be obtained from Rutgers University, Department of Sanitation, New Brunswick, New Jersey.

Study of Pulp Industry Air Pollution Approved by N.C.S.I. Group

At a recent meeting of the South Central Region, National Council for Stream Improvement, a proposal sponsored jointly by the Public Health Service and the N.C.S.I. to develop analytical and sampling techniques and to produce a manual on atmospheric emissions in the Kraft pulp industry was unanimously approved.

* * *

NUCLEAR ENERGY

President Eisenhower Establishes Radiation Council

President Eisenhower announced August 14, arrangements aimed at centralizing responsibility for providing standards and guidance to executive agencies in developing operating rules and regulations for radiological health protection.

In order to obtain assistance, the President issued an Executive Order establishing a Federal Radiation Council. Members of the Council are—the Secretary of Health, Education, and Welfare, the Chairman of the Atomic Energy Commission, the Secretary of Defense, and the Secretary of Commerce. The President's Special Assistant for Science and Technology will participate as an adviser in the discussions of the Council.

In developing its advice to the President the Council will consult with appropriate Federal agencies and will solicit the views of competent scientific bodies.

The Federal Radiation Council will also take steps designed to further interagency coordination of measures for protection against radiation, and will consult with all Federal agencies which have radiological health responsibilities.

The President also approved a series of recommendations to be carried out upon enactment of proposed legislation under which certain regulatory responsibilities of the Atomic Energy Commission will be transferred to the States by agreement with the Commission as the States equip themselves to assume them. The recommendations were that:

(a) The Atomic Energy Commission have the principal Federal responsibility for preparing the States for the proposed transfer of certain of its regulatory responsibilities.
(b) The Training programs necessary for such transfer be financed and planned by the Commission, and in order to make maximum use of existing facilities and competence, such programs be conducted under cooperative arrangements between the Atomic Energy Commission and the Department of Health, Education and Welfare.
(c) At the termination of this special training program any training of State personnel be conducted within the continuing programs of the Department of Health, Education, and Welfare and other Federal agencies.
(d) The Department of Health, Education, and Welfare continue as the Federal focal point for guidance and assistance to the States with respect to contamination by and biological effects from radiation sources not now under control of the Commission.

National Bureau of Standards Handbook 69

The National Bureau of Standards issued its revision of Handbook 52 as Handbook 69, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure". In general, these follow the recommendations of the International Commission on Radiation Protection (ICRP) for workers and control areas adjacent to radiation installations. On the matter of whole population exposure, the National Committee on Radiation Protection and Measurements

(NCRPM) did not specify maximum permissible levels but acknowledged that the tentative ICRP recommendations are under consideration. For strontium-90, the NCRPM "considers that undue risks to the population will not be incurred by following current policies for a while longer, during which time it is hoped that methods may be established for a meaningful analysis and control of population exposure."

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